Transactions of American Society for Steel Treating

Vol. V May, 1924 No. 5

SPECIAL FEATURES

TRANSACTIONS

of the

American Society for Steel Treating

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THE SPRING SECTIONAL MEETING

THE latest reports from Tri City Sectional meeting committees are to the effect that all plans for this meeting have been successfully carried through and we are assured that this meeting will surpass all previous sectional meetings.

On May 22 and 23, many members of the American Society for Steel Treating will gather at the LeClaire hotel, Moline, Ill., and will take part in the program which has been so successfully arranged by the able committees under the direction of H. B. Bornstein, chairman of the Tri City chapter. Those who are not already acquainted with the members of this chapter and the committees, may look forward to the opportunity of meeting them the latter part of this month. The list of these committees and the members thereof were published in the March and April issues of TRANSACTIONS, but in order that we might refresh your mind, we are again including them. The committees are: REGISTRATION COMMITTEE: C. A. Schoessel; FELLOWSHIP COMMITTEE: C. U. Scott; PAPERS AND PROGRAM COMMITTEE: C. H. Burgston; PUBLICITY COMMITTEE: C. H. Lage, J. F. Lardner and R. Henry; BANQUET COMMITTEE: H. Brown and H. O. Koehler; AUTOMOBILE AND PLANT VISITATION COMMITTEE: A. H. Putnam.

At 10:00 a. m. Thursday, May 22, registration will be held in the lobby of the LeClaire hotel and will be followed by a morning technical session, after which luncheon will be served.

The second technical session will be held in the afternoon. Papers will be presented by C. B. Swander, metallurgist, Wagner Electric Co., St. Louis; Dr. Anson Hayes, Iowa State college,

Ames, Iowa; J. H. Nelson, metallurgist, Wyman-Gordon Co., Worcester, Mass., R. G. Guthrie, metallurgist with the Peoples Gas Light & Coke Co., Chicago, and A. S. Kinsey, Stevens Institute of Technology, Castle Point, New Jersey.

On Thursday evening, a banquet will be held jointly with the Tri City Engineers' club and the Tri City Manufacturers' association, at which time, Dr. George K. Burgess, president of the

LeCLAIRE HOTEL
Moline, Illinois

Society and several notable speakers will be guests of the societies.

For Friday, May 23, the committees have made arrangements for plant visitation in both the morning and afternoon. For those who would prefer to play golf, the committees have made arrangements for a golf tournament to be held over the Rock Island Arsenal golf course Friday morning. Trophies have been provided for the winners of this match. It is reported that the Rock Island golf course is the finest in the middle west and it behooves all those who are expert at this sport to bring along their clubs and show what they can do.

The LeClaire hotel will be headquarters for this meeting and provides a very excellent meeting place for this meeting. Reservations may be made by writing directly to the hotel management who have pledged their fullest co-operation and will take care of the needs of all. The rates for rooms in this hotel are $2.50, $3.00 and $3.50 for single person. It has been indicated that there are plenty of rooms at $2.50.

HISTORICAL BOSTON

THE annual convention of the American Society for Steel Treating to be held in Boston, Sept. 22 to 26, 1924, offers an exceptional opportunity for the members of the society, their guests and friends to visit a city that has many points of historical interest, dating back to the birth of the nation. For that reason it has been planned to carry a short series of articles on the points of interest in Boston and vicinity

Bunker Hill Monument
Charlestown

so that our members may be able to use their time to the best advantage in observing these renowned features of historical interest.

Boston, founded in 1630, now has a population of more than 750,000, and is ranked seventh among cities of the United States. Greater Boston, however, contains more than twice that number of people, for within a radius of 12 miles from the State House there is a population of 1,900,000. The met-

ropolitan district is made up of 40 cities and towns, under separate governments yet sharing the benefits and expenses of parks, water supply and sewage systems.

Boston was founded in 1630 and incorporated as a city in 1822. It was originally an irregular peninsula extending into the basin and connected with the mainland by a neck so narrow that there was barely room for a road over it, and so low that water often covered it at high tide. This neck was gradually extended, and the filled-in land now has an acreage greater than that of the original. This madeland includes the entire Back Bay region and much of the lower part of the city.

The crooked streets and narrow alleys of the old part of Boston undoubtedly will be both interesting and confusing to the visiting A. S. S. T. members. The streets of the early Boston followed the lines of greatest convenience which ultimately developed into the unmethodical arrangement of the present city.

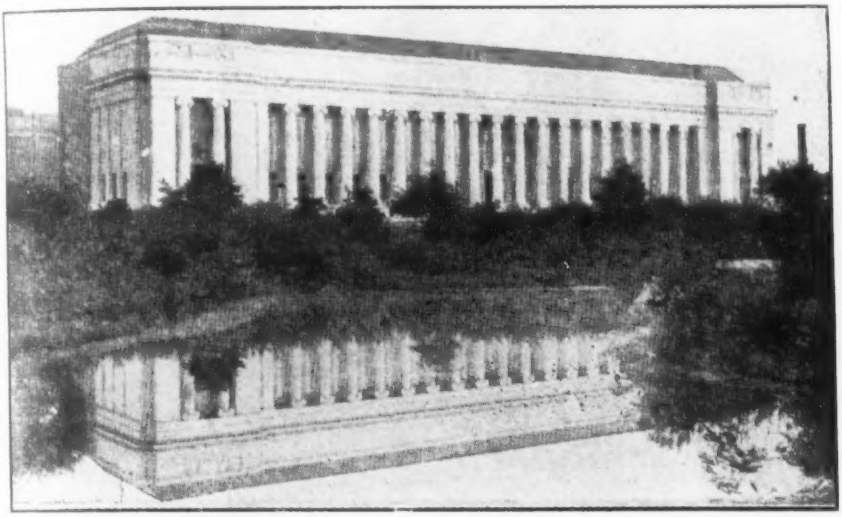
CHARLESTOWN

Charlestown contains the navy yard, Bunker Hill monument, John Harvard monument, and is the birthplace of Samuel F. B. Morse, the world-renowned inventor of telegraphy. Morse's birthplace is on Main street near Thompson Square. In the old graveyard on Phipps street (near Thompson Square) is a monument to John Harvard, erected in 1828 by graduates of the university; but he was buried near City Square in a yard that has long since passed out of existence.

The navy yard is located at the junction of Wapping and Water streets, a short walk from City Square, and is open to visitors through the main gate. The site of the navy yard is the point where the British soldiers landed at the time of the battle of Bunker Hill, June 17, 1775. The frigate Constitution—"Old Ironsides," is anchored nearby.

Bunker Hill monument stands on Breed's Hill, the place where the battle was actually fought, and is reached through Monument avenue, which leads from Main street to the hill.

The monument is on the southeast corner of the place occupied by the American redoubt; it is 30 feet square at the base and 220 feet high. The cornerstone was laid by Lafayette in 1825, Daniel Webster delivering the oration. In the building at the base of the monument are interesting memorials of the battle, including the marble statue of General Warren, by Henry Dexter. The spot where Warren fell is marked



Museum of Fine Arts
Fenway Facade

by a stone in the ground near the lodge. A bronze statue of Colonel Prescott, by W. W. Story, stands in the main path and occupies the spot where the colonel stood at the opening of the battle when he gave the memorable command, "Don't fire till I tell you! Don't fire till you see the whites of their eyes!"

By climbing the 295 steps of the monument one may get a splendid view of harbor and city.

Museum of Fine Arts

The Museum of Fine Arts was founded in 1870 and opened in the building of the Boston Athenaeum. In 1876 new quarters in Copley Square were occupied, although the building was not completed until three years later. In 1890 the building was nearly doubled in size, but even this space was

soon outgrown. The present site of 12 acres was secured in 1899 at a cost of $1,200,000, including later improvements. Several years were spent in study of museums and art galleries in this country and abroad, as well as a special study of lighting effects, before the form of the new building was decided upon. As then completed, it was opened to the public in 1909, provision being made for additions as required.

Appeal to the Great Spirit

The original part was no more than finished when a gift by Mrs. Robert D. Evans made possible the building of the new Fenway front. The building is of Maine granite, and when completed will occupy a quadrangle 486 by 630 feet. It may be described as a group of museums under one roof, as each department is a museum complete within itself and may be visited without going through any other department; yet all are so arranged and related that they may be visited in proper sequence. The space in each is devoted to collections compactly arranged and to rooms for study. The design of each is determined by the light needed.

The Museum of Fine Arts ranks among the most important art museums of the world. As a whole it is excelled in this country only by the Metropolitan Museum of New York, and in some departments it has no superior. The Japanese art collection is the largest and richest to be

found outside Japan. The art galleries contain some of the best American productions and a rare collection of "old masters."

On the lawn in front of the museum stands Cyrus Dal-

Christ Church (Old North)
Salem Street

lin's beautiful bronze statue, "The Appeal to the Great Spirit."

The institution has been supported entirely by the generosity of its friends, with no appropriation from city or state. Admission is free. Open 9 a. m. to 5 p. m.; Sundays, 1 p. m. to 5 p. m.

The Old North Church

Christ Church, "The Old North" of Longfellow's poem, is the chief point of interest in the Salem street of today. This is the oldest church building in Boston (1723), and it was the second Episcopal church to be established in the town. From the steeple of this building were hung the

signal lanterns, as arranged by Paul Revere, that friends of the Charlestown side might be informed of the movements of the British in case Revere was prevented from crossing. The church contains the first peal of bells brought from England, where they were cast in 1744, and are of remarkably good tone. Paul Revere as a young man was one of a guild of eight bell ringers.

The Esplanade

The Esplanade

The beautiful Esplanade along the Charles river basin is a favorite promenade. This basin, now protected from the tide by the Charles river dam, where stood the old Craigie bridge, immortalized in Longfellow's poem, "The Bridge," furnishes an ideal place for all kinds of water sports.

The Public Garden

The Public Garden is just across Charles street from the Common. It is entirely made of filled-in land, and is the beginning of the Back Bay district. The filling of the Back Bay was done by the commonwealth and the Boston Water Power Co. in the years following 1857. The commonwealth owned 108 acres, and after making large gifts to institutions as well as reservations for streets and buildings, it realized the tidy sum of $4,000,000 from the sale of the made land. The Public Garden is about one-half the size of the Common. It is the beauty spot of the city during the summer months, a huge flower garden with a great

variety of trees and shrubs as well as flowers. An artificial pond of irregular shape, with picturesque swan boats and graceful swans, adds much to its beauty. Fountains, statues and monuments enhance the charm. There are several ex-

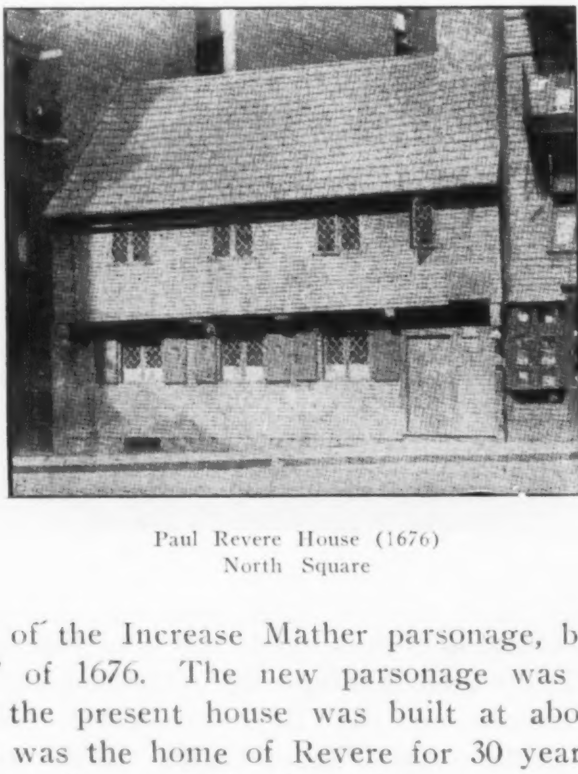
Public Garden

cellent monuments in the Public Garden, the last erected being that of Wendell Phillips by Daniel Chester French in 1914. It stands on the Boylston street side. Statues to Charles Sumner (by Thomas Ball, 1878) and Colonel Thomas Cass (Richard E. Brooks, 1889) are also on the Bolyston street side. Facing Arlington street church is the monument to William Ellery Channing. Arlington street church was the successor to Federal street church where Channing preached. The statue by Herbert Adams stands within a canopy designed by Vincent C. Griffith. It was erected in 1903. Near Beacon street is the bronze statue of Edward Everett by W. W. Story (1867). The Ether monument is a shaft of granite and red marble (by J. Q. A. Ward, 1868). The equestrian statue of Washington, by Thomas Ball, stands near the center walk, facing Arlington street. It

was erected in 1869 through popular subscription. The statue of Edward Everett Hale (Bela Pratt, 1912) is near Charles street.

Paul Revere House

The Paul Revere house stands on the north side of the square. This is the oldest building in the city. It stands



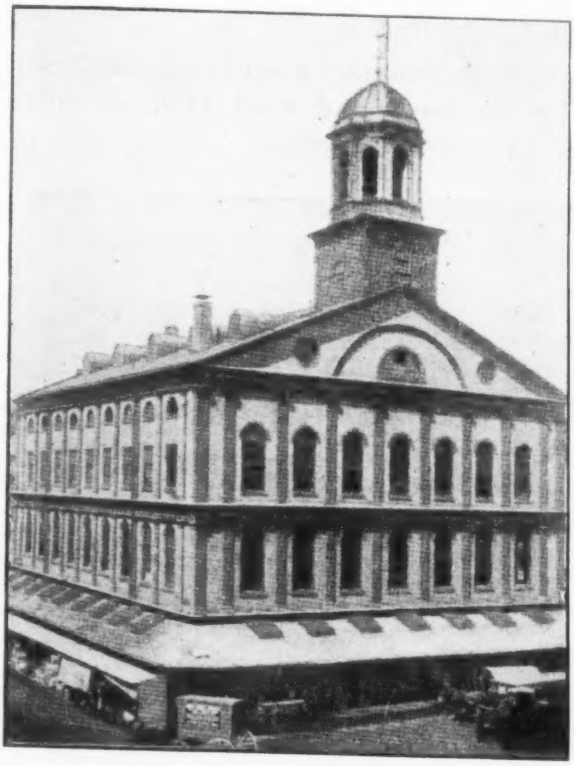
Paul Revere House (1676)
North Square

on the site of the Increase Mather parsonage, burned in the "great fire" of 1676. The new parsonage was on Hanover street, but the present house was built at about the same time. This was the home of Revere for 30 years—1770-1800. Through the efforts of the Paul Revere Memorial association it is now restored to its original condition. The immense fireplaces, the ancient wall paper, the quaint little "entry," and many other features of the colonial period, make this a charming spot in the midst of the babel of the foreign-speaking section. A small admission fee is charged.

Faneuil Hall

Faneuil Hall, "The Cradle of Liberty," is but a short walk from the Old State House, through Exchange street or the picturesquely narrow Change avenue. The first Fan-

euil Hall, the gift of Peter Faneuil, was built in 1742. The interior was destroyed by fire 20 years later, but it was at once rebuilt on the same walls. The hall as it stands today dates from 1805, when the building was doubled in width and raised one story, under the direction of the famous ar-



Faneuil Hall

chitect, Charles Bulfinch. The upper floors of the building are used as an armory by the Ancient and Honorable Artillery company. This is the oldest military organization in the country, having been started in 1637. Its museum contains many priceless relics, including a flag of the organization used in 1663. In the main hall may be seen Healy's painting, "Webster's Reply to Hayne." This canvas, 16 by 30 feet, contains portraits of 130 senators and others prominent in the public life of the time. This hall is never rented, but is used free of charge for any important gathering of citizens. The first floor and basement of Faneuil Hall are still

used as a market—one of the objects for which Peter Faneuil gave the original building.

Commonwealth Pier

The Commonwealth pier where the exposition is to be held, covers 75 acres of water and is owned by the commonwealth of Massachusetts. It was constructed by the state in order to assist in commerce and was taken over during the World war by the navy and used as a shipping base.

It is still in use as a freight loading and unloading dock

Commonwealth Pier

but the larger portion of the pier, devoted to the unloading of passenger boats, has not been used of late, due to the decrease of immigration. It is this passenger portion which is 120 feet wide and 1200 feet long that has been granted to the society for use for exposition purposes.

GOLDEN GATE CHAPTER

A NEW chapter of the American Society for Steel Treating has been formed in San Francisco and vicinity.

There were about 18 members in the vicinity of San Francisco, a large majority of whom had been in contact with the

activities of chapters in other centers, and through the mutual co-operation of these men they were able to bring together a sufficient number for a preliminary meeting. At this meeting, plans were laid for the formation of a temporary organization. A petition for a chapter was drawn up and directed to the national officers of the American Society for Steel Treating. Arthur N. Armitage, of the Columbia Steel Corp., Pittsburg, Cal., was chosen temporary chairman, and D. Hanson Grubb, secretary of the Pacific Scientific Co., San Francisco, was chosen temporary secretary.

The second meeting was held on April 12. A general notice had been sent out to those interested, informing them of the purpose to form a chapter, thus giving them an opportunity to join in signing the petition to the board of directors.

This meeting was held in the industrial gas display laboratory of the Pacific Gas & Electric Co., one of the largest public service corporations of its kind in the country, and was preceded by a dinner. The meeting was a great success and resulted in the definite decision to proceed with the formation of a chapter.

Following the business meeting a formal paper was presented by Professor Welton J. Crook, of the department of metallurgy, Stanford university, and consulting metallurgist for the Pacific Coast Steel Co. His paper, entitled "Steel," included a general outline of the history of metallurgy with particular application to heat treating, going back to earliest history and coming up to the present day. He then gave an outline of the progress that has been made on the Pacific coast in the manufacture of steel and its heat treatment, including a resume of the present status of the industry. Finally, from his experience in his profession and as an educator, he gave some valuable suggestions as to methods whereby the meetings of the chapter could be made of definite assistance to the industry.

Professor H. C. Biddle, instructor of metallurgy at the State Teachers' college, and Professor Morley, University of California also contributed suggestions as to the future activities of the new chapter.

The petition to the board of directors of the American Society for Steel Treating for a charter was then made available for

signatures, and was signed by 102 men, thus making them charter members of the new chapter.

A motion was duly made and unanimously carried that the name of the new chapter be the Golden Gate chapter.

A committee was appointed to arrange for the next meeting to be held on Wednesday, May 14.

The Golden Gate chapter in its initial bow to the American Society for Steel Treating has a new record in securing 102 new members at the time of organization, the largest previous number being 78.

It is needless to state that the entire membership of the American Society for Steel Treating welcomes the new chapter and sincerely wishes it great success and prosperity, knowing full well that it will fulfill the purpose for which it was organized and thus be of inestimable value to the members and industries they represent.

DR. KOTARO HONDA AND ASSOCIATES GUESTS OF THE SOCIETY

DR. KOTARO HONDA, professor of physics and metallurgy at the Research Institute of Iron, Steel and Other Metals, Imperial university, Sendai, Japan, has been visiting the various industrial centers in the United States on his way to spend the summer in Germany, France and England. Traveling with Dr. Honda are two of his associates, lecturers in metallurgy, Messrs. Hiromu Takagi and Tokujiro Matsushita. These gentlemen have been the guests of various chapters of the American Society for Steel Treating where they have visited.

On Wednesday, April 2, in Cleveland, Professor Honda was the guest of honor of the American Society for Steel Treating at a luncheon at the University club, and on Wednesday evening, he delivered an address on the "Theory of Quenching" in the lecture room of Case School of Applied Science.

From Cleveland the visitors went to Pittsburgh where they were met by a committee from the Pittsburgh chapter of the Society consisting of the past president, T. D. Lynch, chairman W. J. Merten and chairman-elect, Duray Smith. They visited many plants in Pittsburgh and vicinity and on Friday evening, April

4, were the guests at a dinner and reception at the Pittsburgh University club after which Dr. Honda delivered an address before the chapter in the auditorium of the Bureau of Mines.

The Philadelphia chapter of the Society entertained the distinguished savants at a dinner on Wednesday evening, April 9, and Dr. Honda addressed the members of the chapter in the assembly room of the Engineers' club.

From Philadelphia they went to Washington where they were the guests of Dr. Burgess, director of the Bureau of Standards and president of the American Society for Steel Treating.

From Washington they proceeded to New York and were guests at a meeting of the New York chapter on Wednesday, April 19. On the twenty-first of April they sailed for England to attend the May meeting of the British Iron and Steel institute to be held in London. This will have been the first meeting of the institute that Professor Honda has attended since receiving the Bessemer medal in 1921.

Dr. Honda previously studied two years in Germany and expects to renew his old acquaintances abroad.

The party plans to return to Japan through the United States in September and have arranged their itinerary so that they will be present in Boston during the convention and international steel exposition of the American Society for Steel Treating. Dr. Honda and his associates have prepared papers for presentation at that time.

HEAT TREATMENT DEFINITIONS*

IN EVERY way commendable are the efforts of the American Society for Steel Treating to clear up the looseness and inaccuracy of terms used in connection with the heat treatment of steel. A tentative set of nine general definitions, drawn by a subcommittee of that organization, was made public last month. These have been submitted to other societies. To most of the definitions little objection can be made. They have to do with processes and represent the best opinion of the largest society directly concerned. The coining of "loneal" to fit the practice involved in heat treating sheets and similar material may be open

*An editorial published in the April 24, 1924 issue of *Iron Age*.

to question. The burdening of technical language with entirely new words is to be avoided. Possibly "sub-anneal" would better describe the conditions where material is heated to a point below that for regular annealing, or below the recalescence point, followed by cooling. Careful consideration should be given the definitions submitted. The experience represented in such organizations as the American Society for Testing Materials and the Society of Automotive Engineers will be of decided help in shaping the final product. Clearness in conception and exactness in terminology are necessary to the right development of this art, which has made such remarkable strides in recent years.

NEW CONSTITUTION

THE new constitution of the American Society for Steel Treating submitted to the vote of the membership has been approved and is now in effect.

This new constitution is the result of the continuous and painstaking efforts of Samuel M. Havens, member of the board of directors and chairman of the Constitution and By Laws committee, assisted by Messrs. Howard J. Stagg, Jerome Strauss, H. K. Briggs and W. P. Woodside. The almost unanimous verdict by which the new constitution was accepted is the highest compliment that can be paid to the excellent work of this committee, and is probably an unprecedented vote in the annals of technical societies.

The report of the Committee of Tellers follows:

"This is to certify that the undersigned, a duly appointed Committee of Tellers, opened and counted the ballots of the members of the American Society for Steel Treating on the new constitution, and by-laws for the Society—with the following results:

Total ballots cast		1775
Those voting "Yes"	1757	
Those voting "No"	12	
Defective ballots	6	
Total	1775	1775

(Signed) L. H. STRANAHAN,
D. M. GURNEY,
C. G. SCHONTZ, chairman.

HEAT TREATMENT OF ALUMINUM-COPPER ALLOYS*

By A. Portevin and F. LeChatelier

Abstract

The authors of this paper have studied the properties of light aluminum alloys containing varying proportions of copper, manganese and magnesium. This paper discusses the characteristics of alloys containing copper, with and without magnesium. The heat treatment and aging of these alloys are discussed at considerable length. The effect of aging and heat treatment upon the physical properties is included.

Hypotheses explaining the constitution of aluminum-copper-manganese-magnesium alloys are given. The authors state that magnesium is not an indispensable constituent of high strength aluminum alloys and indicate the advantages of an alloy which does not contain magnesium.

INTRODUCTION

THE action of quenching and annealing on light aluminum alloys has been interpreted as resulting from the variation of the solubility in solid aluminum of the two definite compounds Mg_2Si and $CuAl_2$; a variation of solubility which has been determined by the outline of the curves of solubility in the solid state which have resulted from the important work of Rosenhain, Hanson and Gayler [1,2] for the compound Mg_2Si, and of Merica, Waltenberg-Scott and Freeman[3,4] for the definite compound $CuAl_2$ (Fig. 1 and 2); curves that have permitted the correlation of the changes in microstructure and the variations of mechanical properties brought about by the quenching.

These transformations in the solid state, by variation of the mutual solubility of the constituents, have also been revealed di-

1. The numbers refer to the bibliography which appears at the conclusion of this paper.

*Translated from the French title, "Le Traitement Thermique des Alliages Legers d'Aluminium a Base de Cuivre," by A. Portevin and F. LeChatelier, Paris, France.

A paper presented by title before the fifth annual convention of the society, October 8-12, 1923, Pittsburgh. This paper was written in French and translated for publication in TRANSACTIONS.

rectly by the study, as a function of temperature, of the physical properties, such as the expansibility and the electrical resistance[5]. In particular the expansibility has permitted the transformations to be followed which occur both at a variable and at a constant tem-

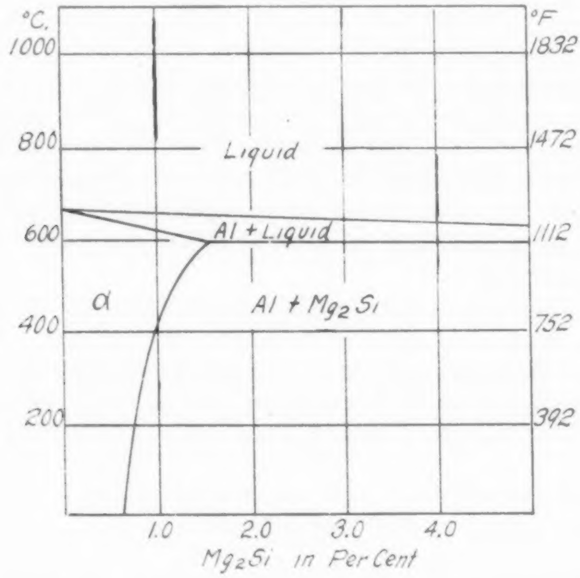


Fig. 1.—Solubility curves of magnesium silicide in aluminum. (Hanson and Gayler).

perature, thus revealing the mechanism of the phenomena of quenching (Portevin and Chevenard)[6].

It follows that these quenched alloys can be classed in two clearly distinct categories:

1.—*Alloys containing magnesium* in which the compound Mg_2Si is present, the silicon being an inevitable impurity of commercial aluminum or having been introduced intentionally to increase the content. Alloys of this category, called *duralumin*, may contain other metals, such as copper, manganese, zinc, etc.

2.—*Alloys containing copper but no magnesium* in which the quenching phenomena are due exclusively to the compound $CuAl_2$; they similarly may also contain other metals, such as manganese, nickel, etc.

The heat treatment of the alloys of this latter category will be exclusively considered in this study. But first, we shall recall the essential characteristics of the heat treatments of the alloys of the first category (alloys containing magnesium) as they result

from the work already cited and that of Wilm[7], Grard[8], Guillet, Galibourg and Durant[9,10], Jeffries and Archer, and Honda.

CHARACTERISTICS OF ALLOYS CONTAINING MAGNESIUM

Hardening after quenching can occur at room temperature. The speed of hardening naturally varies with the temperature; it is an exponential function of the latter. The hardening and the

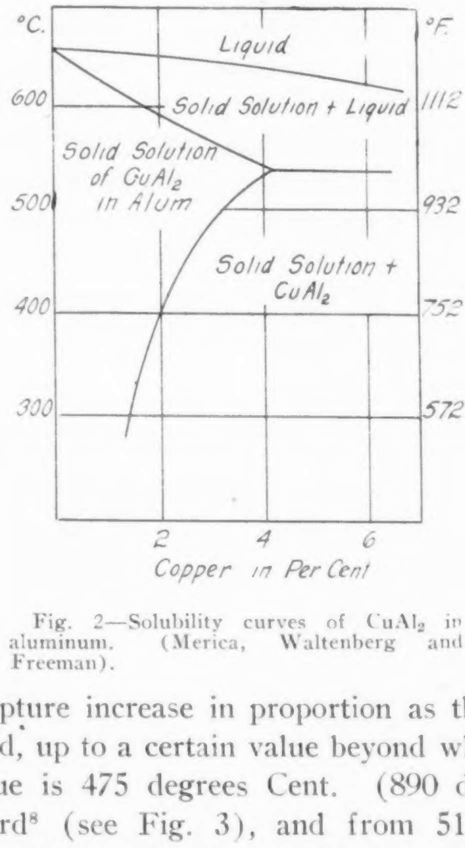


Fig. 2—Solubility curves of $CuAl_2$ in aluminum. (Merica, Waltenberg and Freeman).

elongation at rupture increase in proportion as the quenching temperature is raised, up to a certain value beyond which the elongation drops; this value is 475 degrees Cent. (890 degrees Fahr.) according to Grard[8] (see Fig. 3), and from 510 to 525 degrees Cent. (950-977 degrees Fahr.) according to Merica, Waltenberg and Scott[4]. The following are the results of some quenching tests made by these latter authors:

No.	Alloy Content Copper	Alloy Content Magnesium	Quenched in Water from 525°C. (977°F.) Tensile Strength lbs. per sq. in.	Elong. %	Quenched in Water from 533°C. (991°F.) Tensile Strength lbs. per sq. in.	Elong. %
C8	1.67	1.07	46,215	23.0	34,839	5.0
			44,935	25.5	40,385	9.0
			Quenched in Water from 510°C. (950°F.) Tensile Strength lbs. per sq. in.	Elong. %	Quenched in Water from 533°C. (991°F.) Tensile Strength lbs. per sq. in.	Elong. %
C11	2.58	1.26	51,192	21.0	48,064	9.5
			50,481	24.0	46,926	10.0

In all of the alloys studied, the passage from elastic deformations into permanent deformations is progressive. The fixing of a numerical value for the elastic limit of these alloys is therefore purely arbitrary. In order to give a value at least comparable to elastic limit, we have restricted ourselves to the following method:

We have used a testing machine which traced to the same scale the diagrams of all the tests made. The elastic limit was taken from the diagram, always by the same operator.

After normal treatment, that is to say after quenching in water from between 475 to 500 degrees Cent. (887-932 degrees Fahr.) and aging for about ten days at room temperature, the following results were commonly attained:

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elong. % on 50 mm. (2 inches)
51,192 to 59,725	31,284 to 42,660	20 to 25

As an example, here are some results noted in technical publications:[12,13]

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation % 50 mm. (2 inches)	Reduction of Area %
59,440	35,123	21.1	29.5
55,316	33,417	25.5	26.0
51,192	26,876	25.0	34.0
62,568	39,816	17.6	21.7
65,412	36,688	17.5	21.0
59,155	34,981	21.1	29.5
63,990	40,243	17.6	22.0

The Cahier des Charges de l'Aeronautic Francaise permits the following mechanical specifications for duralumin:

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation in 100 mm. (4 inches)
51,207	31,293	14.0%

The elongation is measured on 100 millimeter gage length (4 inches), on the standard 13.8-millimeter (0.543 inch) test piece. This condition of elongation greater than 14 per cent on a 4-inch gage length, is equal to an elongation of over 19 per cent measured on a 50 millimeter (2-inch) gage length.

Alloys Containing No Magnesium

With alloys of the second category, on the other hand (copper alloys without magnesium), it has never been possible up to the present to obtain these results:

Merica[1] observed the following strengths on sheets:

Copper Content	Annealed Tensile Strength lbs. per sq. in.	Quenched and Aged Tensile Strength lbs. per sq. in.
2.15 per cent	21,330	28,440
3.19 per cent	22,652	31,285

Rosenhain[14], and then Hanson and Gayler[11] took up the systematic study of aluminum-copper alloys. The latter have studied the treatment of the alloys containing from 0 to 5 per

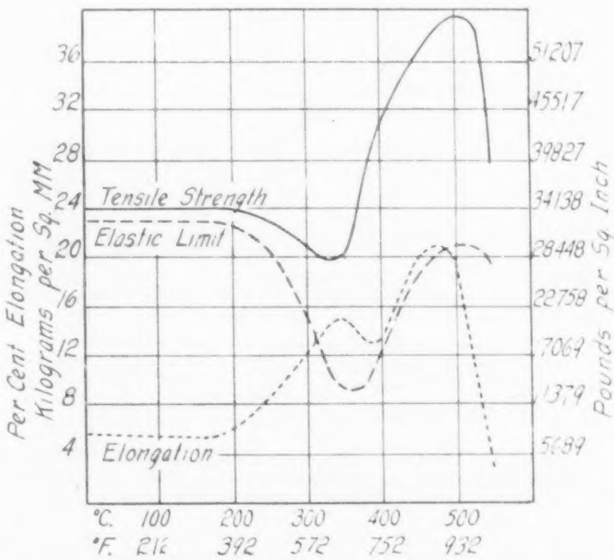


Fig. 3—Curves showing the variation of mechanical properties of aluminum-magnesium-copper alloy as affected by the quenching temperature. Specimens aged 8 hours at 20 degrees Cent. (Grard). Original metal hardened by cold rolling.

cent of copper. The hardening upon quenching at 500 degrees Cent. in water is regular and very marked for alloys containing from 2 to 5 per cent of copper. The hardening by aging at different temperatures is less marked and less regular. Fig. 4 shows the strengths obtained in tensile tests on sheets 2.5 millimeters (0.098 inch) thick. In this case, the best results were obtained after aging at the room temperature. Neither of these

authors has studied the hardening of an aluminum-copper-manganese alloy nor found a commercial interest in the manufacture of the quenched and aged alloys without magnesium.

New Process for Treating Alloys Without Magnesium

It is to be noticed that in the experiments that we are about to mention, the quenching temperature was limited to 525 degrees

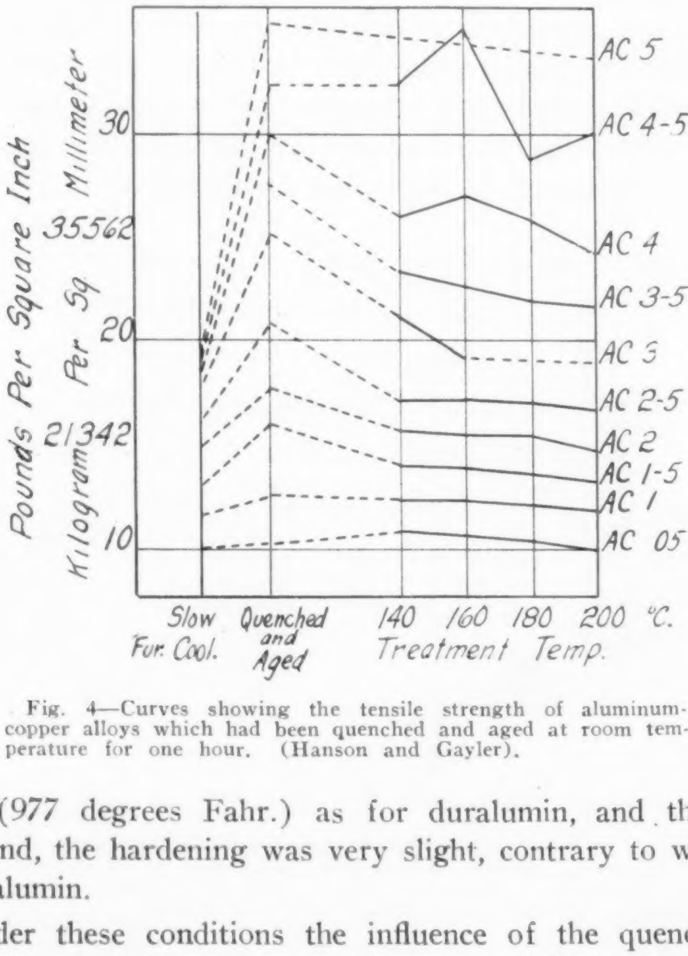


Fig. 4—Curves showing the tensile strength of aluminum-copper alloys which had been quenched and aged at room temperature for one hour. (Hanson and Gayler).

Cent. (977 degrees Fahr.) as for duralumin, and that on the other hand, the hardening was very slight, contrary to what occurs for duralumin.

Under these conditions the influence of the quenching temperature is relatively weak, as is shown especially in the results obtained by Guillet for an alloy with 3.6 per cent copper[10].

Quenching Temperature		Hardness after Aging
Degrees Cent.	Degrees Fahr.	at 100 Degrees Cent.
350	662	38.5
425	797	39.5
475	887	42.5

We shall set forth here researches which show that by com-

bining quenching at a temperature greater than 525 degrees Cent. (977 degrees Fahr.) with aging at a temperature greater than 100 degrees Cent., mechanical characteristics are obtained comparable, and even superior, to those of duralumin. The new products obtained in this way therefore differ entirely from duralumin, not only from the viewpoint of chemical composition, since magnesium

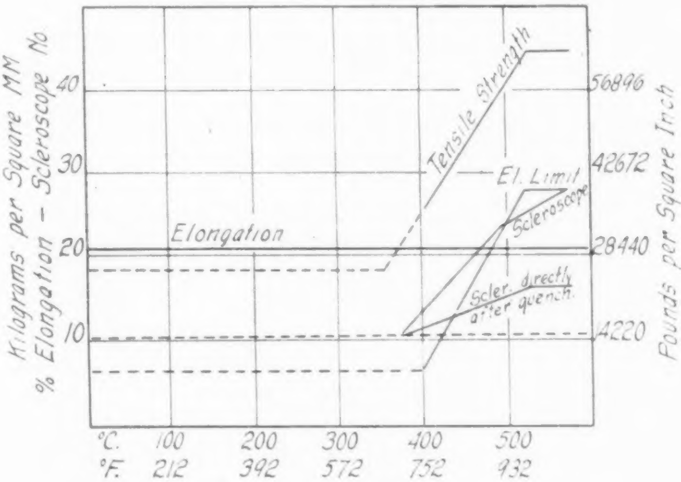


Fig. 5—Mechanical property curves showing the influence of quenching temperature upon a 1.5 millimeter sheet, quenched from varying temperatures between 400 and 575 degrees Cent. (752 and 1067 degrees Fahr.). Specimens aged for 300 hours at 110 degrees Cent. (230 degrees Fahr.)

is absent, but also from the viewpoint of heat treatment, since this is carried out under conditions which would lead to a deterioration of the magnesium alloys.

We shall take as an example the study made on an alloy having 4 per cent of copper and 1 per cent of manganese in rolled sheets. We reserve for exposition elsewhere the influence of the chemical composition (especially of the proportions of copper and manganese), as well as the treatment of these alloys in *cast* pieces, which enables a strength in excess of 42,500 pounds per square inch to be obtained.

Influence of the Quenching Temperature

A series of test pieces cut from sheets 1.5 millimeters thick (0.059 inch) with a composition of 4.3 per cent copper and 0.8 per cent manganese, were quenched at temperatures varying from 400 to 575 degrees Cent. (752-1067 degrees Fahr.), and

were tested after aging for 300 hours at 110 degrees Cent. (230 degrees Fahr.). The results obtained have served for plotting the curves in Fig. 5. Here is clearly seen the progressiveness of the tempering, which begins between 350 and 400 degrees Cent. (662-752 degrees Fahr.) and is complete at 525 degrees Cent. (977 degrees Fahr.). All the properties measured agree on this subject. The dotted lines indicate the properties of the annealed metal. It is curious to note that, for every quenching temperature, the hardening by quenching is always half the hardening by aging.

The averages of the tests made on three different casts show that there is a slight advantage in quenching between 550 and 575 degrees Cent. (1022-1067 degrees Fahr.).

Tensile Strength lbs. per sq. in.	Quenched in Degrees Cent.	Water from Degrees Fahr.
62,568	525	977
63,279	550	1022
63,990	575	1067

Aging Temperature

Sheets quenched in water from 565 degrees Cent. (1044 degrees Fahr.) were aged at 4 different temperatures:

Degrees Cent.	Degrees Fahr.
20	68
78	172
110	230
150	302

Fig. 6 shows the increase in hardness during the aging.

The influence of the aging temperature is of the first order. Aging at 20 and at 78 degrees Cent. (68 and 172 degrees Fahr.) did not permit an appreciable hardening to occur until after several hundred hours. Aging at 110 degrees Cent. (230 degrees Fahr.) developed maximum hardness in 250 hours, which was also reached by an aging of 32 hours at 150 degrees Cent. (302 degrees Fahr.).

However, the temperatures of 150 degrees Cent. (302 degrees Fahr.) is not always preferable to lower temperatures; tensile tests show, indeed, that two test pieces of the same metal, quenched together and set to age, one at 110 degrees Cent. (230 degrees Fahr.), the other at 150 degrees Cent. (302 degrees Fahr.), until the same maximum Brinell hardness is obtained, are not comparable in any way.

Here, for example, are the results of tests made on two 13.8-millimeter diameter (0.543 inch) test pieces from cast 181 (copper 6.0 per cent, manganese 1.17 per cent) quenched in water from 550 degrees Cent. (1022 degrees Fahr.).

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation % 50 mm. (2 in.)	Reduction Area %	Brinell Hard. 1000 Kg. 10 mm. ball.
Aged 50 Hours at 150 degrees Cent. (302 degrees Fahr.)				
64,843	47,210	17.0	37.0	129
Aged 200 Hours at 110 degrees Cent. (230 degrees Fahr.)				
62,284	36,688	25.0	39.0	117

Although the tensile strength and the Brinell hardness are practically identical, the elastic limit is much higher and the

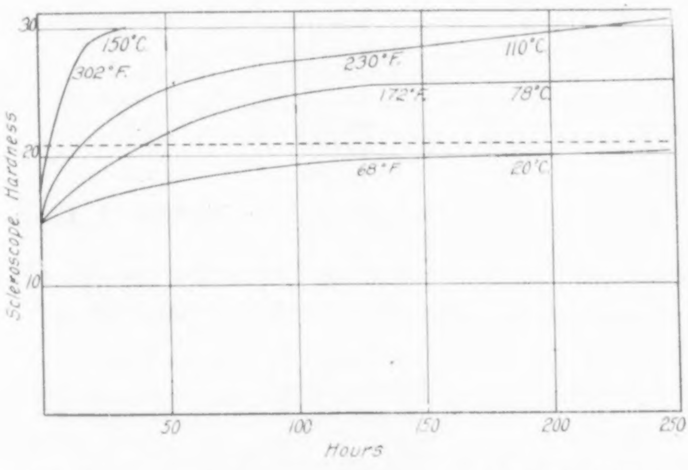


Fig. 6—Influence of aging temperature on the rate of hardening aluminum alloys without magnesium. Specimens quenched in water at 565 degrees Cent. (1049 degrees Fahr.).

elongation much less after aging at a high temperature.

This very important circumstance makes it possible to modify the treatment according as it is desired to obtain, with the same alloy, as high an elastic limit as possible, or great toughness. Duralumin even at room temperature already undergoes an aging as complete as that of the copper-manganese alloy at 150 degrees Cent. (302 degrees Fahr.); there can be therefore, no question of modifying its properties by an appropriate aging treatment.

The temperature of 150 degrees Cent. is the maximum aging temperature for hardening; above this temperature softening begins through annealing of the metal.

Duration of Aging

Fig. 7 shows the progression of the mechanical characteristics as a function of the time of aging. At a temperature of 110 degrees Cent. (230 degrees Fahr.), we usually age for 200 to 300 hours. Prolongation of aging above this time is impossible for a commercial product. It is furthermore without interest. The tensile strength reaches its maximum value with aging for 300 hours. The elastic limit continues to increase at the expense of the elongation; but these same properties are much more economically obtained by brief aging at 150 degrees Cent. (302 degrees Fahr.).

The following results of prolonged aging tests forming a continuation of those which served for plotting Fig. 7 are given:

Sheet 155 Air Quenched from 575 degrees Cent. (1067 degrees Fahr.)
Aged at 110 degrees Cent. (230 degrees Fahr.)

Time of Aging	Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation % (2 inches)	Scleroscope Hardness
23 days	64,275	41,950	19.0	29
76 days	64,275	49,059	14.5	32.5
172 days	63,990	49,770	14.0	32

Mechanical Properties of These Alloys

We shall see that the following properties can be obtained with sheets of copper-manganese alloy, without magnesium:

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elongation % in 4 inches (100 mm.)
Aging 200 Hours at 110 degrees Cent. (230 degrees Fahr.)		
56,880—59,725	28,440—35,550	20—22
Aging at 150 degrees Cent. (302 degrees Fahr.)		
62,568—65,412	35,550—49,770	15—20

Interesting mechanical properties were also obtained on standard test pieces, 13.8 millimeters (0.543 inch) in diameter. The following results were obtained with three casts of slightly different composition.

Table I
Physical Properties

Cast	Temp. of Quench Deg. C.	Temp. of Quench Deg. F.	Time of Aging Hours	Temp. of Aging Deg. C.	Temp. of Aging Deg. F.	Ten. Str. lbs. per sq. in.	Elastic Lim. lbs. per sq. in.	Elong. % 4 in.	Elong. % 2 in.	Red Area %	Brinell Hardness
151	575	1067	80	115	239	53,609	35,550	21	..	44.0	92
151	550	1022	200	118	244	55,458	30,289	23.5	..	48.0	104
180	550	1022	200	118	244	55,174	29,862	22	28	47.0	107
181	550	1022	200	118	244	62,284	36,688	19.5	25	35	117
180	550	1022	50	150	302	51,903	34,555	15	22	41.5	104
181	550	1022	50	150	302	64,843	47,210	13	17	37	129

Comparison of these results and those given for duralumin shows on the one hand that the alloys without magnesium permit equal tensile strengths to be reached, and that on the other hand, according to the treatment used, the alloys without magnesium combine with a given tensile strength either an elongation or an elastic limit greater than those of duralumin.

Toughness

We have noticed in the course of our tests, that metal aged at 110 degrees Cent. (230 degrees Fahr.) had a toughness much

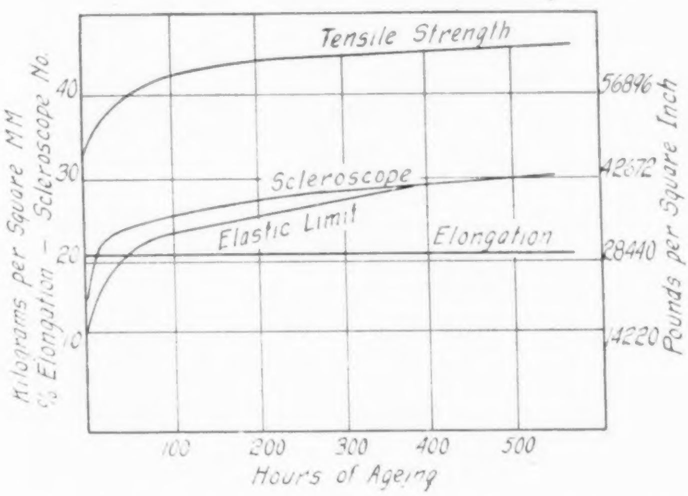


Fig. 7—Hardening action due to aging aluminum-copper alloys without magnesium. Specimens quenched in air at 575 degrees Cent. (1067 degrees Fahr.) and aged at 110 degrees Cent. (230 degrees Fahr.).

greater than that of duralumin. The reduction of area is moreover the clearest experimental criterion of this. It varies for metal having a tensile strength of 54,000-57,000 pounds per square inch, from 25-40 to 45-50 per cent; for metal having a tensile strength of 62,500-65,500 pounds per square inch, from 20-22 to 35 per cent. Other tests have shown us this property in a still clearer way.

In order to determine the ease of stamping of a sheet, we carried out the following test with the Persoz apparatus[8, 14]. This test is analogous to the Erichsen test:

A sheet 1.5 millimeters to 2 millimeters (0.059 to 0.78 inches) thick is clamped between two annular jaws having an interior diameter of 50 millimeters (2 inches). One of these jaws rests on

an annular support while increasing pressures are applied to the center of the sheet by means of a ball 20 millimeters in diameter (Fig. 8). The test is stopped on the appearance of the first crack.

As Fremont has noted[17], the appearance of the first crack is indicated in a surer manner, without intervention of the personal factor of the operator, by the diagram which registers the force as a function of the sinking in of the punch.

We have proceeded in that way, stopping the test at the moment, always clearly characterized, when the diagram showed a maximum. The depth of the depression at this moment is a good indication of the ease with which the metal can be twisted, stamped, and bent cold, while the load per millimeter of thickness characterizes the resistance.

Our test gave us the following results:

Table II

Alloys	Treated for Tensile strength lbs. per sq. in.	Treated for pct. Elongation	Thickness m. m.	Breaking Load in lbs. per m m thickness	Depth of Impression Inches
Annealed					
Aluminum			2	913	.610
Duralumin	62,568	15	2	1034	.197
Copper-Manganese					
Alloy 157..........	56,880—63,990		1.5	2017	.358
Copper-Manganese					
Alloy 37..........	56,880—63,990		1.5	1518	.287
No. 143............	56,880—63,990		2.0	1397	.295

Figs. 9 and 10 show tested disks of several types of aluminum-copper-manganese alloys. The data contained in Table II and these photographs show that pure aluminum, an excellent stamping metal, has a low mechanical strength, even after cold-hardening. The quenched alloys stamp much less easily than pure aluminum, but the more tenacious alloys, without magnesium, are better suited to this work than duralumin.

We have tested, quenched but not aged, test pieces under the same condition, obtaining the following result:

Copper Alloy No. 157	Treated for Tensile Strength lbs. per sq. in.	Thickness mm.	Breaking Load per mm. in thickness Pounds	Depth of Depression Inches
	42,660	1.5	2970	.500

In order to give a complicated shape to this metal by stamping it suffices to quench it, and not subject it to any aging. Under these conditions it will be almost as ductile as aluminum. The aging may be done afterward, when the piece is finished. Such a method of working is impossible with duralumin, which hardens by aging at room temperature and thus loses its quality of toughness.

Another toughness test is the enlarging test on tubes, imposed by the Aeronautique Francaise. In this test, a conical mandrel

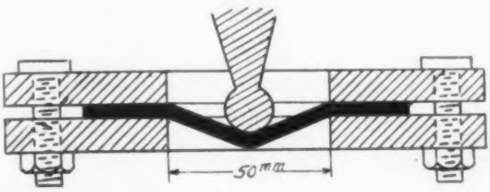


Fig. 8—Diagrammatic sketch of the Persoz apparatus for indentation tests.

with a 45 degree angle (Fig. 11) is forced into a tube until the first appearance of a crack on the tube. The increase in diameter of the tube is measured at this moment. The following results on tube No. 153, having a diameter of 39 millimeters (1.54 inches, and a thickness of 4 millimeters, (0.157 inch) were obtained:

	Percent Expansion
Annealed metal	28.5
Metal treated for 56,880 lbs. per sq. in	24.5

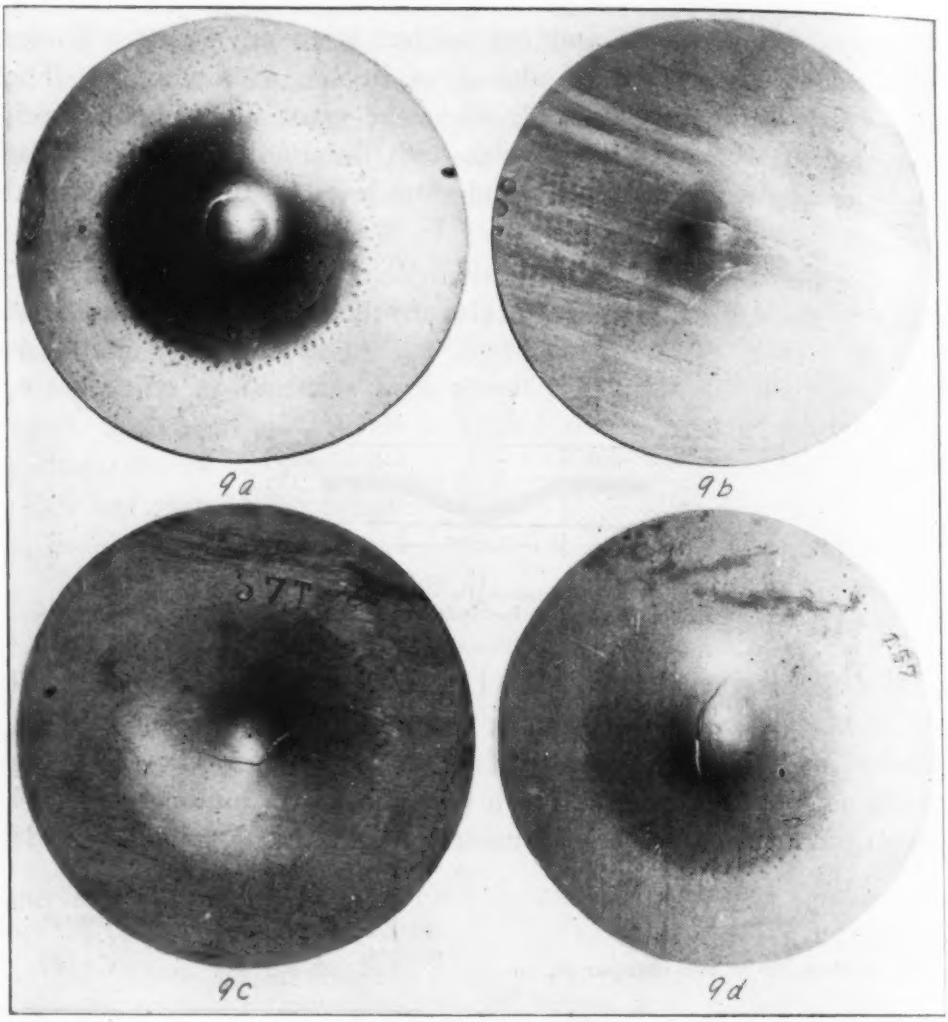
Cahier des Charges Francaise for duralumin tubes of the same dimensions—treated metal, specify a reduction area of 9 per cent.

The sample tested was therefore three times better than required by the Cahier des Charges for duralumin.

Properties When Hot

The authors have studied the hardness ,when hot, of duralumin and the alloy without magnesium in both the annealed and the quenched state; using for this study a Brinell apparatus having a 10-millimeter ball under a 500-kilogram load.

In the annealed state, the two hardness curves are identical;



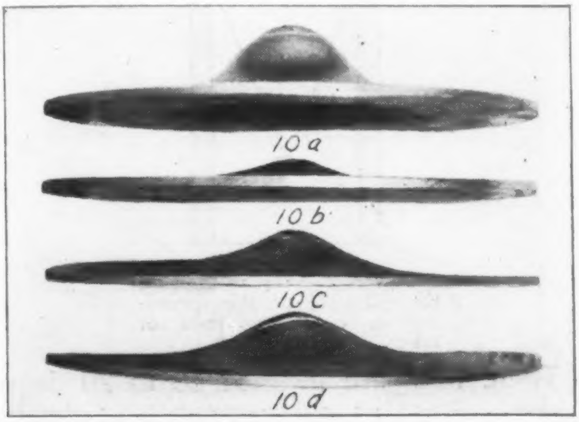
Figs. 9a-d—Indentation tests of pure aluminum and aluminum-copper alloys. Fig. 9a—Annealed aluminum, No. 159; Fig. 9b—Treated duralumin, No. 158; Fig. 9c—Treated copper alloy containing 4 per cent copper and one per cent manganese, No. 37; Fig. 9d—Same as Fig. 9c, No. 157.

the working conditions of these two alloys, drawing, rolling, spinning, forging, will thus be the same. For the quenched metals, the treatment undergone and the time of maintenance at the temperature will have a marked effect on the hardness. There is indeed, for these alloys, at every temperature, either an increase of hardness by aging or a softening by annealing.

We have plotted in Fig. 12 the hardness curve after an hour of treatment at each temperature; it shows in very clear fashion

the complete annealing above 200 degrees Cent. (392 degrees Fahr.). We do not lay stress upon the difference in the courses of the two curves between 20 and 150 degrees Cent.; it is partly due to slight differences in the treatment of the two test pieces.

We have drawn on Fig. 12, the hardness curve obtained with duralumin by Colonel Grard[8]. The very marked difference between



Figs. 10a-d—Indentation tests. Fig. 10a—Annealed aluminum, No. 159; Fig. 10b—Treated duralumin, No. 158; Fig. 10c—Treated copper alloy containing 4 per cent copper and one per cent manganese, No. 37; Fig. 10d—Same as Fig. 10c, No. 157.

this curve and ours, probably indicated that the tests were made after holding between 200 and 400 degrees Cent. (392-752 degrees Fahr.) for some minutes, insufficient to give time for the annealing to take place.

Oscillations

In the course of this study of quenched light aluminum alloys, we have observed the following phenomenon. In breaking by pulling, either cylinder test pieces selected from drawn bars or flat test pieces selected from sheets, the stress, instead of increasing in a continuous manner, progresses by repeated oscillations, the amplitude of which may reach 4 per cent of the total load, and the frequency of which is several oscillations per second. The stress-strain curve registered by the machine, presents the appearance shown in Figs. 13 and 14. The amplitude of these oscillations increases with the load up to the maximum of the mean curve.

The speed of loading corresponds to an elongation of 8 per cent per minute.

At the same time there appeared on the surface of the flat test pieces, the lines of slipping known as Piobert, Hartmann or

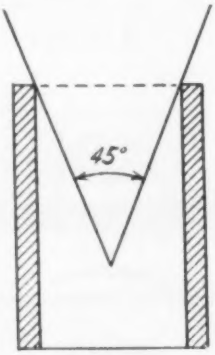


Fig. 11—Sketch showing the principle of the spreading or expanding tests of tubes.

Luders lines. These lines are inclined 60 to 70 degrees from the direction of the stress; they belong to two conjugate systems, symmetrical with respect to the axis of the test piece; each oscillation of the load appears to correspond to the releasing of a series of slips which propagates itself as a series of waves from one end of the test piece to the other. The arrival of each wave train is accompanied by a little dry noise, perfectly perceptible at a distance of several feet.

Generally, all the successive wave trains are parallel to each other. The appearance of the first conjugate line of them causes the local constriction and determines rupture.

The tests were made with an Amsler testing machine. The inertia of the manometer pendulum probably influences the outline of the diagram, either by modifying the form of the observations or by regulating the frequency by resonance. This phenomenon has not been observed, however, on any other of the alloys tested with this same machine. The principal interest of this phenomenon is that it occurs only in alloys in course of transformation.

The phenomenon described reaches its maximum amplitude immediately after quenching. The oscillations are the weaker and commence after the greater permanent deformation, the more prolonged the aging has been. They disappear when the transformation is ended. A softening annealing causes them to reappear.

The curve in Fig. 13 was obtained with an alloy without magnesium of the type:

Copper	Manganese
4.5 per cent	0.8 per cent

This alloy gave a tensile strength immediately after quenching

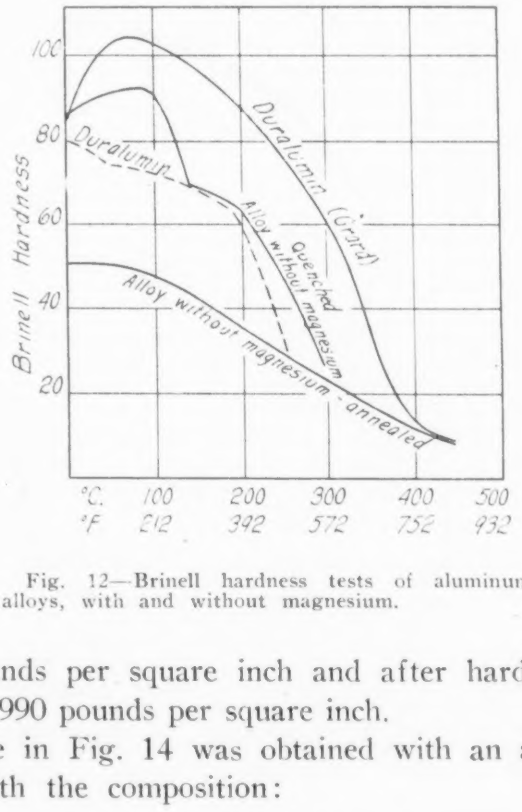


Fig. 12—Brinell hardness tests of aluminum alloys, with and without magnesium.

of 45,500 pounds per square inch and after hardening a tensile strength of 63,990 pounds per square inch.

The curve in Fig. 14 was obtained with an alloy containing magnesium with the composition:

Copper	Manganese	Magnesium	Silicon
4.8 per cent	0.6 per cent	0.5 per cent	0.3 per cent

This alloy gave a tensile strength after quenching of 46,925 pounds per square inch and after hardening a tensile strength of 63,990 pounds per square inch.

As this phenomenon has been observed on alloys of the two types, with and without magnesium, it therefore appears to be connected with the transformation, accompanied by hardening, that occurs after quenching. In this respect, it constitutes a permanent criterion of the progress of the transformation during aging.

This phenomenon of oscillations has also been noticed in some

other metals and alloys. Rosenhain and Archbutt[15] have observed it in aluminum-zinc alloys containing 5 to 25 per cent of zinc. Andre Le Chatelier[16] notes it with respect to mild steel test pieces tested between 80 to 250 degrees Cent. (176-482 degrees Fahr.). Steel containing 25 per cent of nickel has also shown the same

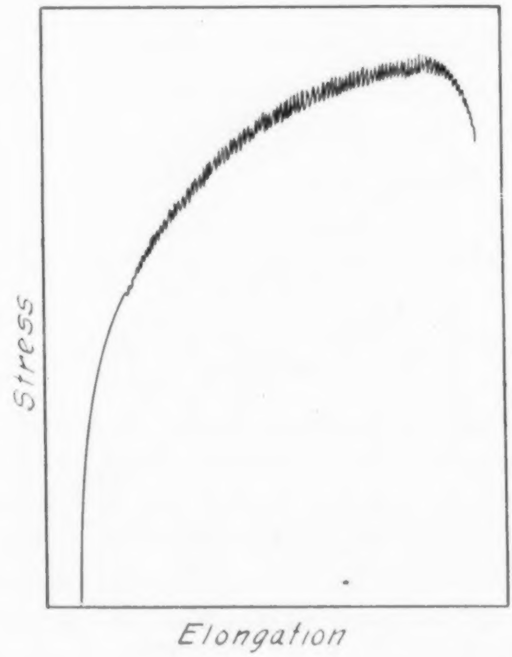


Fig. 13—Stress strain curve of a cylindrical test bar of an aluminum-copper-manganese alloy. It will be observed that the stress instead of increasing in a continuous manner progresses by repeated oscillations, amplitude of which may reach 4 per cent of the total load and the frequency several oscillations per second.

peculiarity in some tests. All these alloys undergo internal transformations of various natures, (generally poorly understood), at a temperature near the testing temperature; they are essentially composed, before transformation of solid solutions containing the various elements, that is to say of a single phase.

Hypothesis Explaining the Constitution of the Alloy Without Magnesium

This alloy greatly resembles duralumin in the principle of its treatment and in its mechanical properties. From the latter point of view the only difference is the slight elongation of annealed

duralumin (14 per cent) instead of the 20 per cent elongation, measured on a 4-inch gage length. This difference is due to the well known property of magnesium, of diminishing the elongation of aluminum. The very similar properties are due to an analogous constitution.

Above 525 degrees Cent. (977 degrees Fahr.), the alloy without magnesium is formed of a solid solution, aluminum, copper and

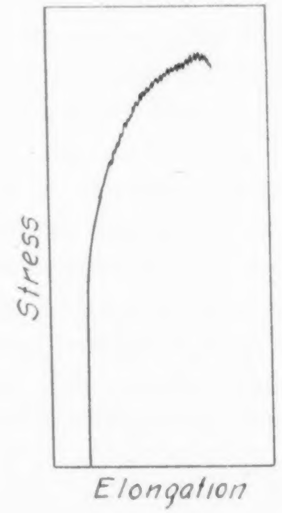


Fig. 14—Stress strain curve of a flat test bar of aluminum-copper-magnesium-manganese alloy showing the oscillation phenomena.

manganese. The addition of manganese does not modify the effect of quenching, but increases the hardness of the annealed metal as well as of the quenched metal.

The proportion of copper in the solid solution decreases with the temperature in the case of slow cooling, by the precipitation of a compound such as $CuAl_2$, starting from the solid solution. Rapid cooling, preserves when cold, the solid solution that is stable when hot. Annealing at 300 degrees Cent. (572 degrees Fahr.) gradually transforms the metal and brings it to a stable state when cold. Aging at 110 degrees Cent. (230 degrees Fahr.) precipitates the constituent $CuAl_2$ in a finely divided state and hardens the metal. Aging at 20 degrees Cent. (68 degrees Fahr.) is not sufficient to transform the metal, which retains when cold, the structure that is stable when heated.

Hardening of duralumin takes place by exactly the same mech-

anism; the addition of magnesium or magnesium silicide has for principal effects:

1. A lowering of the point where melting begins, and a prohibiting of reheating to a temperature above 525 degrees Cent. (977 degrees Fahr.).

2. A lowering by 100 degrees Cent. (212 degrees Fahr.) of the aging temperature, which can take place at room temperature.

From this hypothesis it follows that the alloy without magnesium and duralumin will have practically the same properties for equal proportions of copper, manganese and silicon; but the possibility of quenching the copper-manganese alloy 50 degrees Cent. higher, makes it possible to bring a larger amount of copper into solid solution, and thus to obtain a stronger metal by raising the copper content to 5.5 per cent, the maximum proportion of the solid solution, according to the most recent determinations. For duralumin, on the contrary, it is useless to exceed 4.5 per cent copper, the content of the solid solution at 525 degrees Cent. (977 degrees Fahr.)

The authors' tests have shown that the best strengths were obtained with cast No. 181, having the following composition:

Copper	Manganese	Silicon	Iron
5.8 per cent	1.10 per cent	0.2 per cent	0.2 per cent

A treated 13.8-millimeter (0.543 inch) test piece gave the following results:

Tensile Strength lbs. per sq. in.	Elastic Limit lbs. per sq. in.	Elong. in 4 inches	Elong. in 2 inches	Reduc. Area	Brinell Hardness
62,300	36,687	19.5%	25.0%	35.0%	117

Conclusion

Magnesium is not an indispensable constituent of high strength quenching alloys with an aluminum base. Two alloys containing the same percentages of copper, manganese, silicon, etc., but of which one contains magnesium while the other is without it, present similar properties after suitable treatment. In summing up the differences between these two alloys we find:

1. That the simplicity of aging, as effected at room temperature, is decidedly a favorable property of duralumin.

2. That the omission of magnesium in the second alloy facilitates the manufacture of ingots, for which it is difficult to obtain

a uniform content of magnesium. The metal is tougher and it can be kept indefinitely in the half-hard state after quenching and without aging.

3. That in the magnesium-free alloy, it is possible to obtain different mechanical characteristics with metal from one cast, by changing the aging temperature, and crop-ends can be recast and used again without inconvenience.

4. That in this alloy, the attainment of higher tensile strength resulting from the addition of copper in larger quantities is a decided advantage.

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HARDNESS OF STEEL BALLS BY MAGNETIC TESTS

By S. R. Williams

Abstract

This paper describes a rapid method of determining magnetically, the hardness of steel balls. With the method it is possible to conduct a 100 per cent inspection on balls for hardness, with considerable rapidity.

Illustrations showing the schematic arrangement of the author's apparatus, the set-up and graphs of certain tests made upon balls having different degrees of hardness are incorporated.

Introduction

THE methods more generally employed in measuring hardness are not adaptable to testing steel balls because, as is well known, the process injures the ball and makes the point at which the test was made, a weak spot, prejudicial to its life. There are no satisfactory means at present available for testing the hardness of steel balls, therefore, any attempt at determining hardness by magnetic methods is quite worth while, since the magnetic method does not injure the specimen tested.

In general, the annealing of steel increases its magnetic permeability. This suggests a possible means of testing the relation of hardness to magnetism. If a horseshoe magnet is placed where it controls a magnetic needle of a magnetometer, the field of the horseshoe magnet may be distorted by introducing between its poles a piece of magnetic material, a steel ball for instance, and this distortion of the main magnetic fields gives rise to a deflection of the magnetometer. The greater the permeability of the ball, the greater will be the distortion of the field and the greater the deflection of the magnetometer. Hence, the deflections of the magnetometer will vary from ball to ball, if these have been differently annealed, and consequently have different permeabilities, and therefore, different hardness. The method of determining these factors and the apparatus used, is described herein.

A paper by S. R. Williams, department of physics, Oberlin college, Oberlin, Ohio, and presented before the Pasadena meeting of the American Physical Society, May 5, 1923.

Apparatus and Manipulation

In Fig. 1 is shown a schematic drawing of the magnetic hardometer. B, represents the steel ball which is $\frac{3}{8}$ inch in diameter, and thus gives the key to the relative dimensions of the apparatus, since the drawing has been made to scale. The horseshoe magnet U, which is arranged with an armature so that when

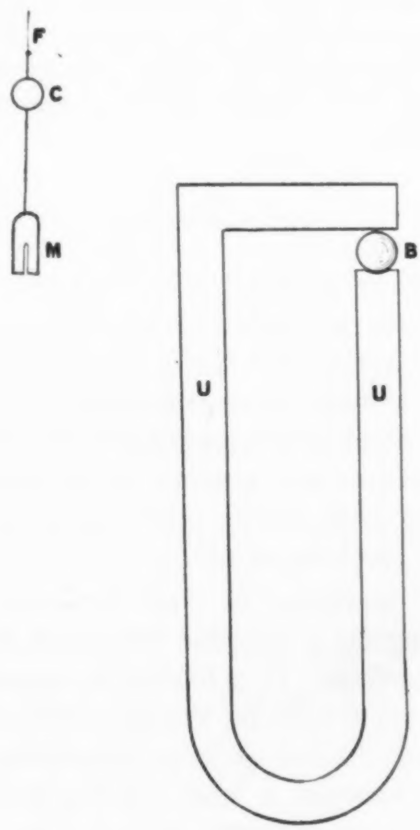


Fig. 1—A schematic drawing of magnetic hardometer.

the steel ball is put in position, it will make as complete a magnetic circuit as possible. The gap in which the steel ball is placed must be adjusted for each size of ball used, or a set of horseshoe magnets may be substituted as different sizes of balls are tested. M, is the bell-shaped magnet of the magnetometer, C, a concave mirror and F, a phosphor-bronze fiber. An illuminated slit is used as the source of light, which is reflected from C, to a ground

glass scale, and by this means, the deflections are read. Fig. 2 shows the apparatus as actually set up.

A plot of the magnetic field surrounding the horseshoe magnet and the magnetometer in a plane normal to the axis of the horseshoe magnet, and passing through the center of the steel ball and

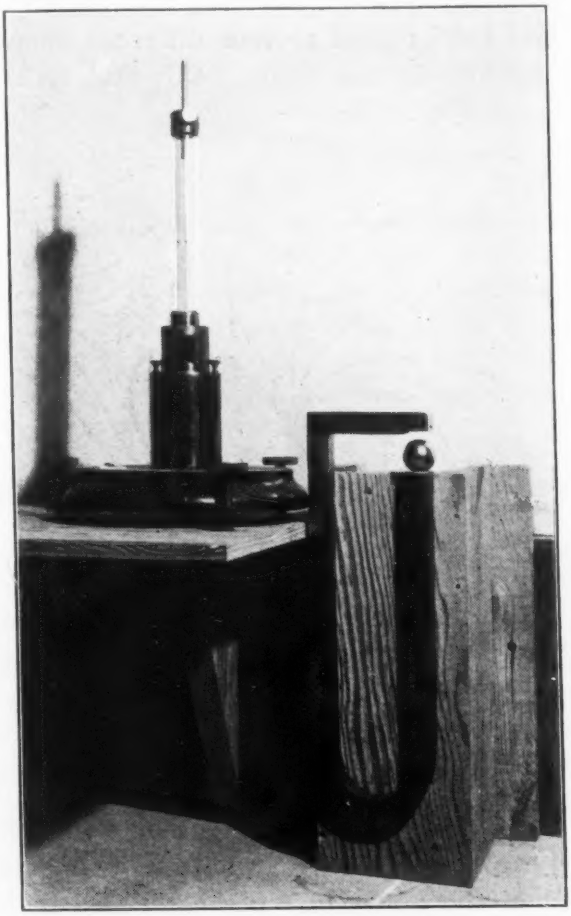


Fig. 2—Photograph of apparatus used in making these tests.

the magnetometer needle, is shown in Fig. 3. X, shows the neutral point of the combined fields of the earth and the horseshoe magnet. O, is the approximate location of the magnetometer as was found by trial. It is the point where the maximum deflection is obtained with stability, when the ball is inserted in the gap of the magnet. The location of the magnetometer is important, for the ability of the instrument to identify steel balls of different degrees of hardness, depends upon the differential readings obtained when steel

balls of different hardness are placed in position in the gap of the magnet.

Results of Tests

Through the courtesy of the New Departure Manufacturing Company of New Britain, Connecticut, the writer was provided with a set of steel balls heated at four different temperatures, viz.; 250, 350, 450 and 550 degrees Cent. (482, 662, 842 and 1022 de-

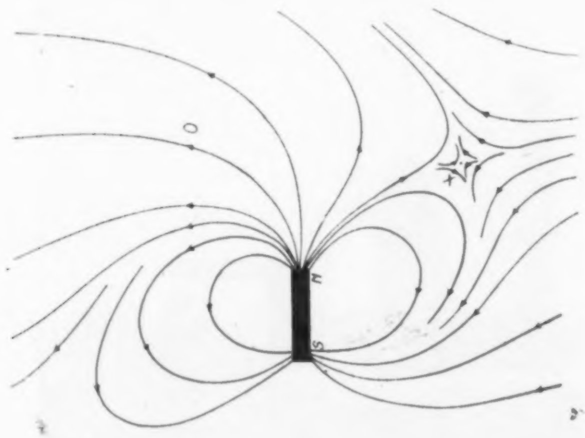


Fig. 3—Diagrammatic sketch of the magnetic field surrounding the horseshoe magnet and the magnetometer in a plane normal to the axis of the horseshoe magnet and passing through the center of the steel ball and the magnetometer needle. X is the neutral point of the combined fields of the earth and the horseshoe magnet. O is the approximate location of the magnetometer.

grees Fahr.) There were three balls to each temperature and the average of the three were taken for each temperature. These balls were tested in the apparatus just described, in which deflections were taken as indicating hardness.

Fig. 4 shows the graph obtained when deflections are plotted against drawing temperatures. Thus it becomes a simple matter to identify steel balls that have been heat treated at different drawing temperatures having the same heating periods. If standard steels could be procured, standards scales of hardness could be adopted. It is a known fact that steel balls which have been given the same heat treatment, do not behave alike in endurance tests, therefore, the information to be determined in this investigation, was whether or not this device could differentiate between steel balls which

had had the same heat treatment, but which may or may not have had the same quality and hardness.

A group of 200 steel balls with the same heat treatment was tested. They were tested magnetically and classified in two broad groups, "uniform" and "nonuniform." Those which were "nonuniform" showed different degrees of permeability in different directions. Those two main groups were then subdivided into two more classes, designated, "soft" and "hard," accordingly as they showed greater or less permeability. In crushing tests those classified as "uniform" and "hard," were definitely superior. Unfortunately, endurance tests were not made, but there seemed to be little doubt that this quality would show a definite correlation with the crushing tests.

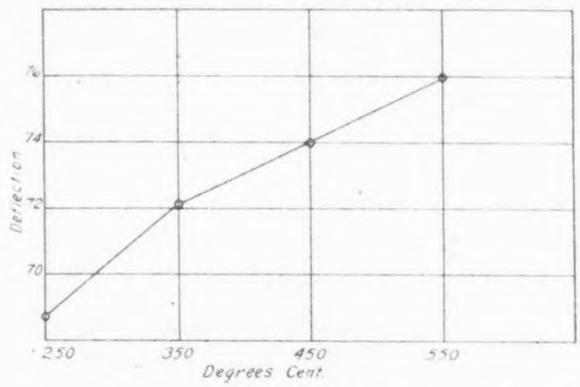


Fig. 4—Graph obtained when deflections are plotted against drawing temperatures.

If in these tests all of the steel balls should prove to be too nonuniform in structure, this device would have no practical use unless it should point the way to the production of a more uniform steel ball, which might give better endurance qualities.

Commercial Application of Method

The instrument herein described, furnishes a method for testing hardness at a speed which is somewhat greater than hand calipering, but for commercial purposes it would doubtless be better to redesign the apparatus so that it could handle the balls more rapidly. It is suggested that manufacturers having the facilities at hand, try the following plan, i. e., to construct a device

whereby the steel balls roll down a chute to a flat surface and then across the pole of an electromagnet. The softer balls would be more strongly attracted and be deflected on the level surface more than the hard ones. This would make possible a separation of the balls into various compartments as they rolled from the level surface.

While the hardness testing device which was actually used in this investigation is a very simple one, it is hoped that out of it may grow other magnetic devices for the hardness testing of steel balls.

These experiments were carried out in the Norman Bridge Laboratory of Physics, California Institute of Technology. The author is indebted to the director, Prof. R. A. Millikan, for the facilities of the laboratory offered in making these tests.

A FEW NOTES ON THE SHIMER CASE HARDENING PROCESS

By B. F. Shepherd

Abstract

This paper incorporates a few notes on liquid case carburizing of certain steels. Curves and photomicrographs are included showing the depths of penetration and the structures obtained on an S. A. E. 6120 steel and an S. A. E. 1112 steel.

THE liquid case hardening baths in general use are cyanide baths, usually sodium cyanide, poisonous in itself, giving off poisonous and obnoxious vapors and making the operating conditions distinctly disagreeable and dangerous for the workmen. The type of liquid carburizing bath used at the Phillipsburg plant of the Ingersoll-Rand Co. since 1917, does not give off any harmful gases and has been found very efficient for case-hardening. This process, invented by Dr. P. W. Shimer, of Easton, Pa., was described in a paper presented by him before the Indianapolis convention of the American Society for Steel Treating and published in the February, 1922, issue of the TRANSACTIONS of the society.

The base of the bath is a mixture of specially selected and prepared sodium and calcium chlorides, commercially obtainable in two grades, No. 950 and No. 1150; these numbers designate the melting points in degrees Fahr. No. 1150 is the grade used in case-hardening. The bath is given case-hardening properties by the immersion in it of small lumps of special calcium cyanamide, to which has been given a registered trade name. Small burst of yellow flame are seen all over the surface while the bath is active. When these yellow flames die down, fresh calcium cyanamide is added to the bath.

The carbon concentration curves of Fig. 1a show the effect of this type of bath upon a chrome-vanadium steel S. A. E.

A paper presented before the Lehigh Valley Sectional meeting of the society, June, 1923. The author, B. F. Shepherd, is metallurgist with the Ingersoll-Rand Co., Phillipsburg, N. J.

6120, immersed in it at the temperatures and for the periods of time indicated in the following tabulation:

Curve No. 1—¼ hour at 1450 degrees Fahr.
Curve No. 2—½ hour at 1450 degrees Fahr.
Curve No. 3— 1 hour at 1450 degrees Fahr.
Curve No. 4— 3 hour at 1450 degrees Fahr.
Curve No. 5— 5 hour at 1650 degrees Fahr.
Curve No. 6—25 hour at 1650 degrees Fahr.

These specimens were of the same size as those described in the writer's paper[1] on solid carburizing compounds, being 5 inches long and 2 inches in diameter. The nitrogen

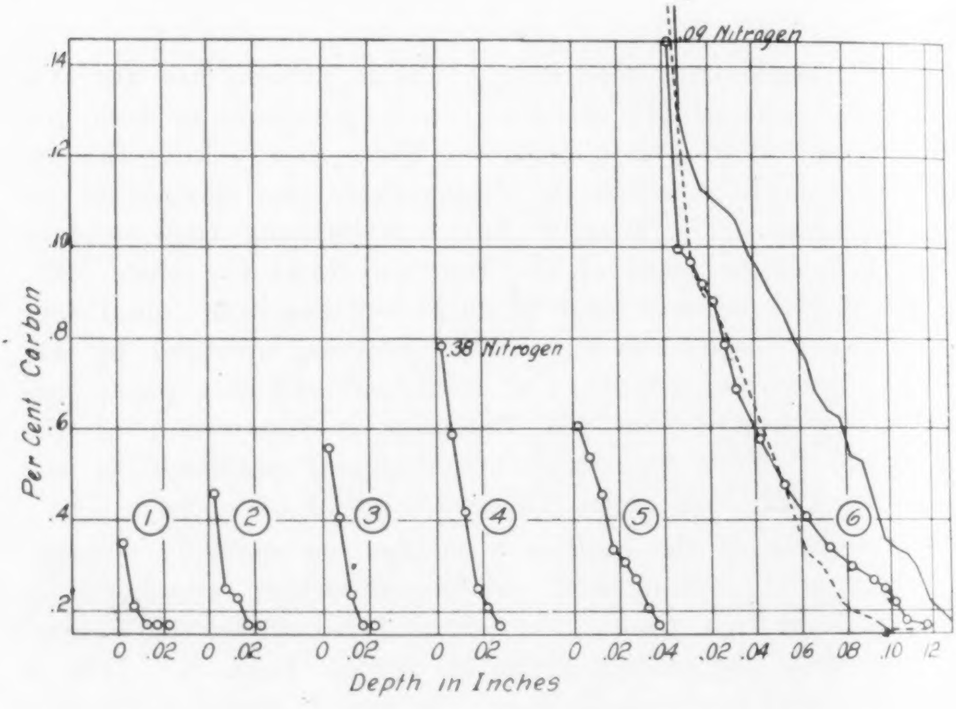
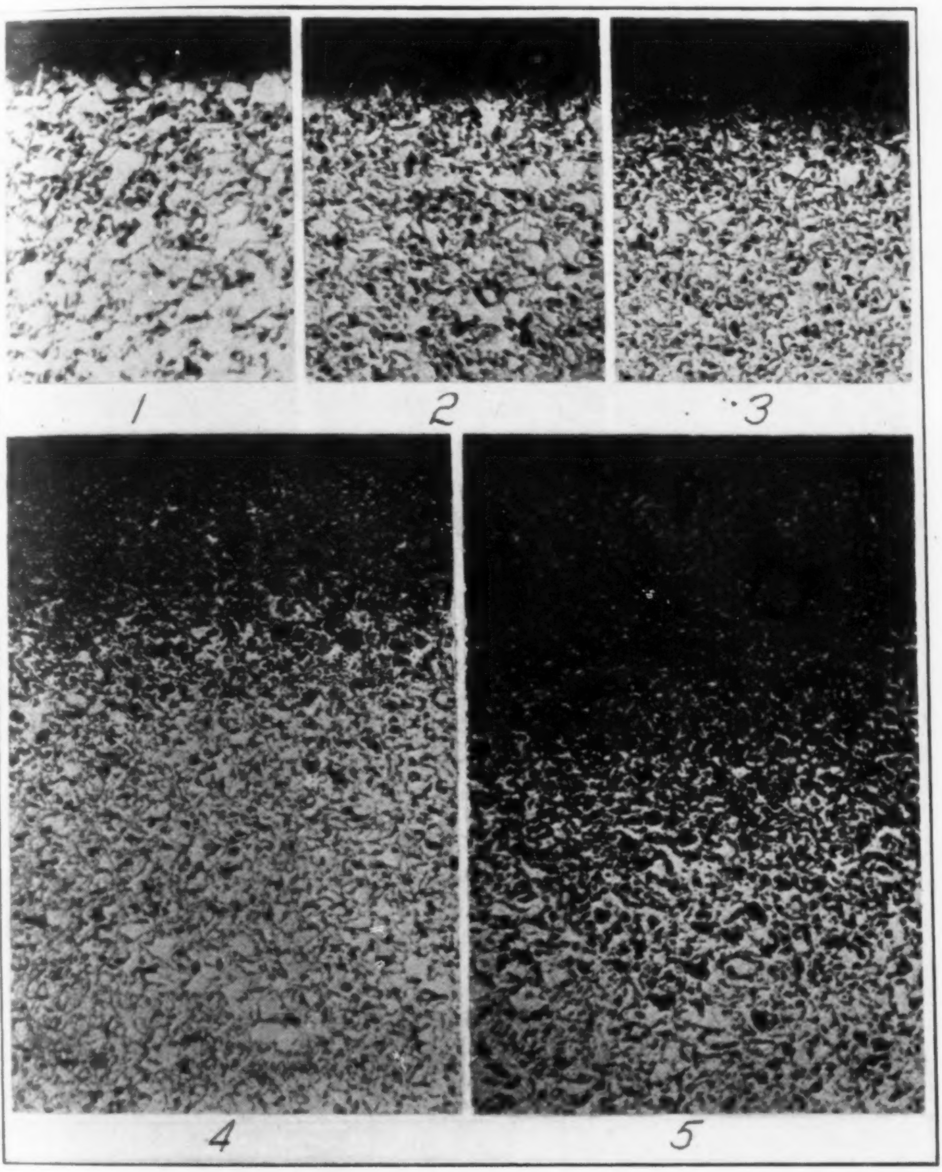


Fig. 1a—Carbon concentration curves showing effects of this bath on a chrome vanadium steel, S. A. E. 6120. Time of immersion at 1450 degrees Fahr.—curve No. 1, ¼ hour; curve No. 2, ½ hour; curve No. 3, 1 hour; curve No. 4, 3 hours. Time of immersion at 1650 degrees Fahr.—curve No. 5, 5 hours; curve No. 6, 25 hours.

determinations confirm the results of Fay[2] that the nitrogen content decreases with rise in carburizing temperature. At the same temperature, this bath gives somewhat higher carbon concentration and lower nitrogen concentration than cya-

1. Transactions of American Society for Steel Treating, Vol. 4, No. 2, page 171.
2. *Chemical and Metallurgical Engineering*, Vol. 24, No. 7, page 289.

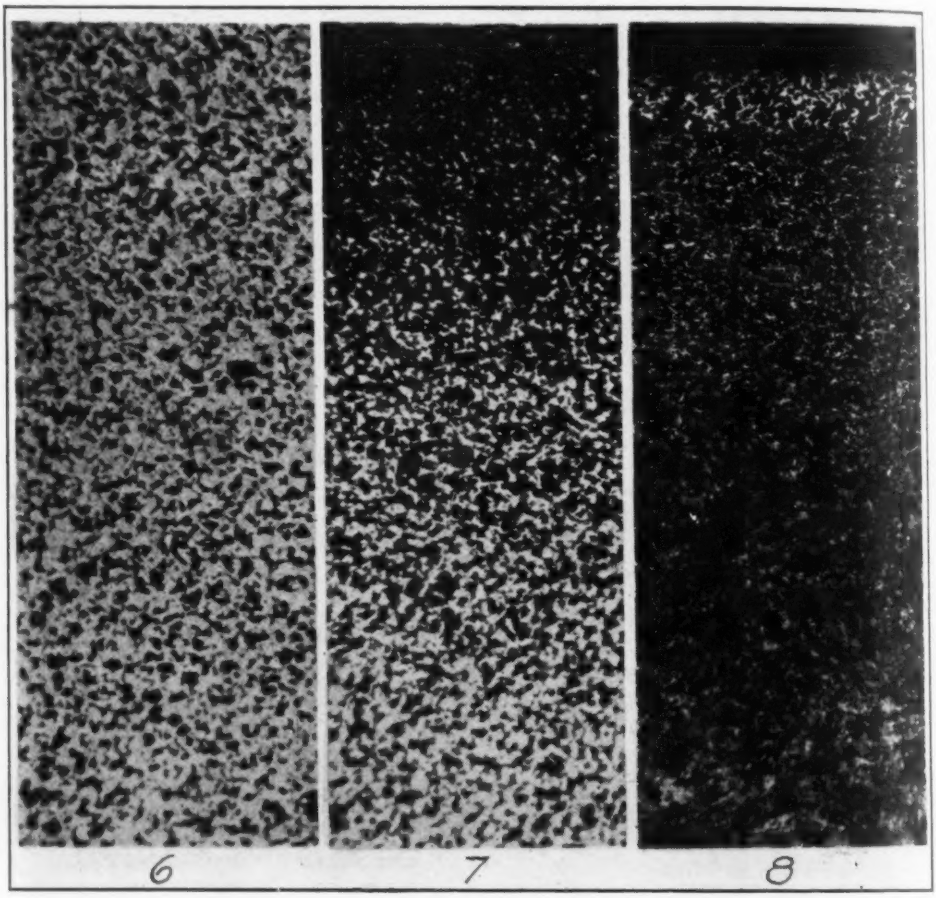


Figs. 1 to 5—Microstructure of case obtained with different periods of immersion in case hardening bath. X 90. The carbon concentration curves of these specimens are shown in Fig. 1a. Time of immersion, for each specimen is Fig. 1, ¼ hour; Fig. 2, ½ hour; Fig. 3, 1 hour; Fig. 4, 3 hours; Fig. 5, 25 hours.

nide, and the hardening action obtained with it appears to be due more to the carbon than to the nitrogen. This is quite desirable, as the generally accepted theory seems to be that nitrogen produces a brittle case.

Two curves have been superimposed on curve No. 6,

Fig. 1a, showing the effect of a well known brand of solid carburizing compound upon a steel of the same analysis. The broken line represents the case obtained with a temperature of 1600 degrees Fahr., 24 hours after heated through; the solid line 24 hours after heated through at 1700 degrees Fahr.



Figs. 6 to 8—Microstructure of the case of the specimens graphically represented in curve No. 6, Fig. 1a. X 90. Fig. 8 shows the extreme outside; Fig. 7 is at a depth of 0.05 inch from the surface and Fig. 6 is at a depth of 0.100 inch from the surface.

The microstructure of the cases given in the various curves is shown in the photomicrographs, Figs. 1 to 8.

A number of pieces of ¼-inch round S. A. E. 1112 steel, were immersed in the bath at 1650 degrees Fahr., each piece was removed, quenched in brine and fractured (Fig. 9). The number of hours of immersion is noted in the caption of

Fig. 9. The depth of case obtained can be compared with the original ¼-inch diameter of the test piece. It is, of

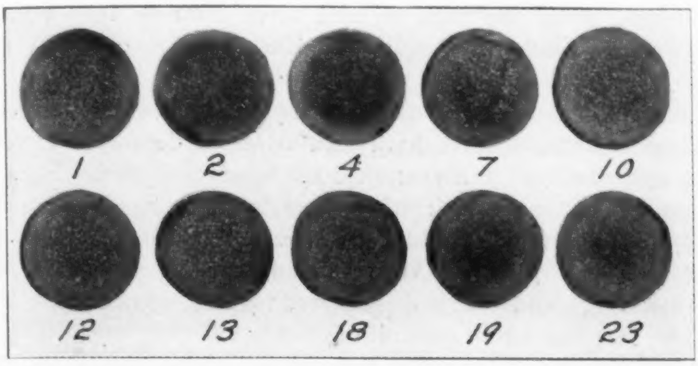


Fig. 9—Macrostructure showing depth of case obtained on ¼-inch round S.A.E. 1112 steel at 1650 degrees Fahr. for the number of hours noted below each fractured specimen.

course, intensified by the smaller ratio of surface exposed, to volume carburized, on such small rounds.

Acknowledgement is made to Dr. William Campbell for the photomicrographs embodied in this paper.

Discussion of Mr. Shepherd's Paper

Following the presentation of this paper, Mr. Shepherd was asked whether or not he had made similar experiments using a sodium cyanide bath at 1600 to 1650 degrees Fahr., and what comparative results were obtained as to carbon and nitrogen penetration and microscopic structure.

Mr. Shepherd stated that no tests were made with a sodium cyanide bath at these temperatures, however, he quoted the following figures[1] with the use of the Shimer bath on the one hand and a pure sodium cyanide bath at 1525 degrees Fahr. on the other. The specimens were immersed for a period of one hour.

	Shimer Bath		Sodium Cyanide	
First cut of 1/200 inch—	C. 0.754%	N. 0.301%	C. 0.622%	N. 0.351%
2nd. cut of 1/100 inch—	C. 0.254%	N. 0.041%	C. 0.268%	N. 0.081%
3rd. cut of 1/100 inch—	C. 0.160%	N. 0.039%	C. 0.108%	N. 0.028%

Mr. Shepherd indicated that the Shimer bath produces a case in a shorter time than the sodium cyanide bath, indicating that the advantages in using this special bath are not confined to the higher tem-

1. Transactions of American Society for Steel Treating, Vol. 2, No. 5, page 407.
Transactions of American Society for Steel Treating Vol. 4, No. 2, page 171.

peratures. The bulk of the work that the author has been doing has been accomplished at temperatures, from 1400 degrees Fahr. and upward. He has found a noticeable advantage over cyanide at all temperatures. He pointed out that the objectionable features in the use of sodium cyanide are much accentuated when the bath is used from 1600 to 1650 degrees Fahr., whereas this special bath at these temperatures is not only effective but is wholly unobjectionable.

He stated that no comparative study of the microstructure of the case produced by this special bath had been made other than to show that satisfactory carbon penetration had been obtained. In support of this, he stated that any lack of proper structure of the parts case-hardened by this method would have been disclosed by this time, due to the fact that the parts so case-hardened are required to withstand the most exacting and rugged service. Many specimens so treated have been in service for a period of 6 years.

He made reference to Giolitti's work in which has been stated that the cyanide—case "exfoliates," but such a condition had not been observed in the experiments with this special bath.

Mr. Shepherd was then asked to state what were the dangerous effects of the use of cyanide baths in hardening. In amplifying the question, the member stated that he had seen cyanide baths used openly and unprotected and in a rather careless manner, however, he had observed no ill effects on the workmen.

Mr. Shepherd answered this question by saying that he had seen no cases wherein workmen had been poisoned by cyanide fumes. However, reports of such accidents had come to his attention.

In reply to the question as to the serious effects on the health of workmen, one of the members indicated that he had seen several cases where workmen have needed medical treatment due to the inhalation of cyanide fumes. The effect of these fumes resulted in a severe headache, nausea and severe bleeding of the nose.

Another member said that he had recently heard of cases wherein one workman died and another was seriously injured through the use of cyanide case-hardening baths, and that in the cases cited, these plants had discontinued the use of this type of bath.

Due to the fact that there seemed to be some doubt as to the effect that cyanide fumes have upon workmen, one of the members suggested that the American Society for Steel Treating could perform a worthy service by conducting an investigation as to the effects of the fumes of heated cyanide upon workmen. A resolution was made conveying to the officers of the society that it was the judgment of the assembled body of members, that such an investigation should be made.

SOME FUNDAMENTAL DEFECTS OF HARDENED STEELS

By Dr. Leslie Aitchison

Abstract

This paper is concerned with certain properties of fully hardened steels that can only be regarded as being of the nature of defects. They are defects in the sense that the steels would be better if they did not possess these properties. Two such "defects" are dealt with in the paper, these being, firstly, the abnormally low value of the limit of proportionality (or what is often called the elastic limit) and secondly, the instability of volume which characterizes hardened steels.

The abnormally low limit of proportionality is found in both quench-hardened and work-hardened steels, but the cause of its presence in the two types of steel is not imagined to be identical. In respect of such hardened steels it is indicated that the low value of the limit of proportionality is associated with the presence of austenite in the steel and that this austenite need not be at all plentiful. This is in accordance with the fact that the low limit of proportionality is found in a great variety of steels—in fact in almost any steel that, after hardening, has a maximum stress of 80 tons per square inch or more. The work-hardened steels owe their low limit of proportionality to the residual effects of straining during cold working and in them the critical constituent is the ferrite that has been made to slip during the working.

Values of limit of proportionality in different hardened steels are given, and it is shown conclusively that there is a very large difference between the actual stress which produces some permanent deformation in the steel, and the stress which is generally called the yield point.

WITH the exception of plain-carbon steels that contain less than 0.35 per cent carbon, it is safe to say that all steels, when in the fully hardened state, have certain definite properties which can be regarded as being defects. They are de-

A paper presented by title before the fifth annual convention of the Society, Pittsburgh, October 8-12, 1923. The author, Dr. Leslie Aitchison, D. Met., B. Sc., F. I. C., is consulting metallurgist, Lloyds Bank Chambers, New Street, Birmingham, England.

fects in the sense that the steel would be very much better if such properties were absent, and in many instances it is worth while to take steps to alter these properties in a way that will be beneficial to the steel. These defects—or some of them—are found in steels that have been hardened either by cold working or by quenching. Steels hardened by quenching may be taken to include those hardened by cooling in oil or water and also those steels that have been cooled in air, but which in cooling thus have hardened up to a strength that is approximately equal to that which would be attained by the same steel when quenched in oil—that is to say, the term includes those steels ordinarily called air-hardening steels. Naturally also the quenched steels include the case-hardening steels.

Low Value of Limit of Proportionality

The first adverse property of these steels that should be referred to, is the abnormally low value of the limit of proportionality. In ordinary language the point called the limit of proportionality is called the elastic limit. Really this latter term should only be used with the greatest reserve and after a careful definition. When such a definition is supplied, it will be found that it simply means that the point referred to is the limit of proportionality under very specific conditions.

It is ordinarily assumed by steel users that the limit of proportionality of a steel is a fairly high proportion of its maximum stress—e. g., 60 per cent, and it is similarly assumed that the limit of proportionality is not very much lower than the value called the yield point—i. e., the stress at which there is a marked permanent extension of the test piece. Such assumptions are based upon another assumption, which is that the stress/strain curve of any steel is of the general form shown in Fig. 1. The steel that gives such a curve has a long range of proportionality, and the departure from proportionality between strain and stress in such a steel is relatively sudden. It may be said generally that normalized mild steels give such a diagram. Fully hardened steels on the other hand give stress/strain curves that are distinctly different from that in Fig. 1. In Fig. 2a is shown the curve for an air-hardened nickel chromium steel, in Fig. 2b, that for an oil-quenched nickel chromium steel, and in Fig. 2c, that for a cold-

worked steel. In all the three curves it is evident that the range of proportionality is quite short and that the departure from proportionality occurs gradually and not suddenly as in the type of steel that gives the kind of curve shown in Fig. 1. The result is that by the time that the curve has bent over sufficiently to produce a degree of permanent deformation that would be noticed in testing, and be recorded as the yield point, the applied stress has

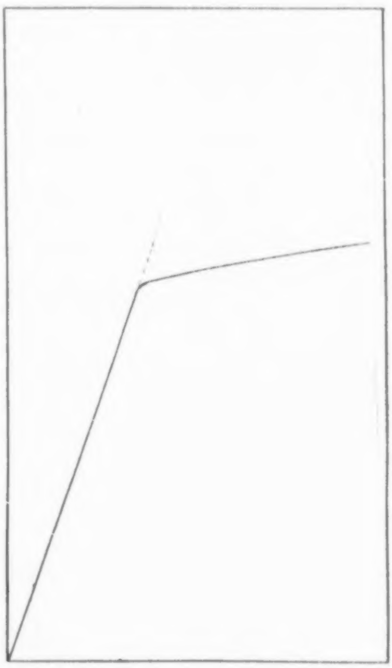


Fig. 1—Stress/Strain Curve Typical of Normalized Mild Steel.

arisen to a value very much higher than the limit of proportionality or the primitive elastic limit. Clearly, therefore, for such steels as are illustrated in Fig. 2 the yield point, so called, as ordinarily determined gives an entirely false idea of the value of the limit of proportionality.

The actual values of the limit of proportionality in some fully hardened steels are shown in Table I. Together with the values of the limit of proportionality are shown those of the maximum stress and of the yield point, so called. These values indicate plainly the great disparity between the values for the limit of proportionality and the yield point, and also show very well the

low ratio between the limit of proportionality and the maximum stress of these steels.

It may be said here that the low values of the limit of proportionality are not by any means accidental or unreal. They are obtained with perfect regularity and they do really represent a stress that produces some permanent deformation in the metal. This being so, it is of importance firstly to realize that they may

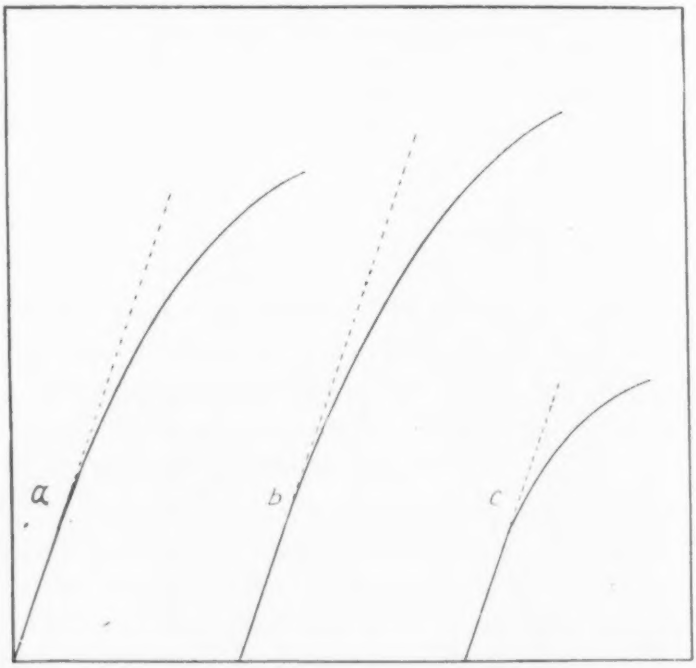


Fig. 2a—Stress/Strain Curve for an Air-Hardened Nickel-Chromium Steel. Fig. 2b—Stress/Strain Curve for an Oil-Quenched Nickel-Chromium Steel. Fig. 2c—Stress/Strain Curve for a Cold-Worked Steel.

be harmful, and secondly to consider whether the value of the limit of proportionality can be raised to a safer figure.

Fortunately it is found that the limit of proportionality of all the fully hardened steels is raised by reheating. The quenched (and air-hardened) steels give the highest value of the limit of proportionality when tempered at a temperature between 350 or 400 degrees Cent. (660-750 degrees Fahr.). Naturally such a treatment reduces the maximum stress from the fully hardened value, so that this treatment cannot be applied in the event of the high-maximum stress being necessary. The change in the maximum stress as well as in the limit of proportionality produced by

reheating an air-hardened nickel chromium steel can be seen in the figures quoted in Table II. In Table III are the values of a similar kind for an oil-quenched nickel chromium steel. In both steels it is evident that the effect of reheating is quite similar.

It is, however, not always possible to go to the extent of tempering at such a temperature as will produce the optimum value of the limit of proportionality, simply because of the drop in the maximum stress and consequently in the hardness. A case in point is an air-hardened gear or pinion. In such a case it seems best to treat the steel at the maximum temperature that can be afforded when taking into account the change in the maximum stress. In general, fully-quenched steel may be tempered at a temperature approximately 200 degrees Cent. (390 degrees Fahr.).

Table I

Actual Values of the Limit of Proportionality in Some Fully Hardened Steels.

Type of Steel	Limit of Proportionality tons/sq. inch	Yield Point tons/sq. inch	Maximum Stress tons/sq. inch
Air-hardened Nickel Chromium Steel A	24.9	83.5	109.4
Air-hardened Nickel Chromium Steel B	20.6	79.5	107.1
Air-hardened Nickel Chromium Steel C	23.8	72.3	98.2
Oil-hardened Nickel Chromium Steel D	27.4	97.2	123.3
Oil-hardened Nickel Chromium Steel E	18.3	106.6	125.9
Cold-worked Steel F	23.1	48.7	60.3
Cold-worked Steel G	27.1	59.2	70.2

Table II

Change in Maximum Stress and Limit of Proportionality Produced by Reheating an Air-Hardened Nickel Chromium Steel

Reheating Temperature Degrees Centigrade	Limit of Proportionality tons/sq. inch	Maximum Stress tons/sq. inch
...	24.9	109.4
100	36.1	103.7
200	59.3	96.8
300	66.2	91.6
400	58.8	83.9
500	54.2	71.3
600	38.9	60.1

without causing too great a fall in the value of the maximum stress. The steel should, however, be tempered for a prolonged period. It is found that tempering even at 100 degrees Cent. (212 degrees Fahr.) will actually raise the limit of proportionality to a value near to the optimum, provided that the tempering be carried on for about three days. At 200 degrees Cent. (390 degrees Fahr.) the tempering time can be reduced very materially and it may be taken, that about four hours at this temperature will be extremely beneficial.

Table III

Change in Maximum Stress and Limit of Proportionality Produced Reheating an Oil-Quenched Nickel Chromium Steel

Reheating Temperature Degrees Centigrade	Limit of Proportionality tons/sq. inch	Maximum Stress tons/sq. inch
...	27.4	123.3
100	34.2	121.6
200	58.3	109.4
300	71.1	100.2
400	65.2	93.1
500	58.7	75.4
600	42.3	64.9

It is further to be noted that the value of the limit of proportionality is not unaffected by the application of fatigue stress. The low limit of proportionality in the fully-hardened steel is accompanied by a low ratio of fatigue range to maximum stress—i. e. the ratio is lower than in the same steel after tempering at a temperature of about 400 degrees Cent. (750 degrees Fahr.). The application of fatigue stresses, however, actually raises the value of the limit of proportionality very considerably, and although it does not raise it to the highest value attainable by tempering, yet it very considerably improves the value—e. g. from 20 tons to 55 tons per square inch. In many instances this treatment alone (which the steel receives automatically when put into service) is sufficient to rectify the low value of the limit of proportionality produced by hardening.

The existence of the low value of the limit of proportionality in quenched steels is connected definitely with the stresses that have been endured by the steel during the actual quenching operation. It seems that wherever any austenite is present in the steel—even in quite small quantities—a low value of the limit of pro-

portionality is found. The presence of austenite is recognized in many steels that have been quenched—certainly in many more than used to be believed. Under these circumstances it is not surprising that there are a very large number of steels which on quenching possess this undesirably low limit of proportionality. It is probably true that all hardened steels having a maximum stress greater than 80 tons per square inch, possess this abnormality. Steps, therefore, should be taken to consistently deal with the trouble along the lines suggested.

It has already been mentioned that the harder cold-worked steels also show this low value of the limit of proportionality. In such steels the cause of the phenomenon is to be found in the changes brought about in the steel during the working process. There seems to be little doubt that the low elastic limit in such steels is the result of the slipping induced in the ferrite of the steel during the cold working. The planes on which slip has occurred have not healed up thoroughly and therefore permit of more ready movement—i. e. inelastic deformation—when submitted to stress, than accurs in a steel that has not been made to slip. This is quite a different matter from that which produces the low limit of proportionality in the quenched steels, but it is found nevetherless, that reheating to a temperature of 350 to 400 degrees Cent. (660 to 750 degrees Fahr.) is sufficient to bring up the value of the limit of proportionality of a cold-worked steel to a definitely high figure. With a cold-worked steel, again there is the well marked difference from the quenched steels, that the former can be reheated safely to the proper temperature for producing a high value of the elastic limit without thereby losing its strength or hardness. Whereas, the quenched steels may lose 20 per cent of their maximum stress when being tempered in order to induce a high limit of proportionality, the same operation applied to the work-hardened steel does not cause any loss of strength and often causes the reverse—i. e. a small increase in the maximum stress. The changes in maximum stress and in the limit of proportionality brought about by reheating a cold-worked steel to different temperatures are shown plainly in Table IV.

With both the quench-hardened and the work-hardened steels, the operation of reheating causes a marked change in the form of the stress/strain curve. Those for the hardened materials are

shown in Fig. 2. The form of curve obtained after reheating to the optimum temperature is shown in Fig. 3.

It is to be noted that case-hardened parts are very definitely prone to suffer from this abnormally low value of the limit of proportionality. Even a plain carbon case-hardening steel is likely in the quenched case to be in a suitable condition of structure and consequently of elastic strain to show the defect, while many alloy

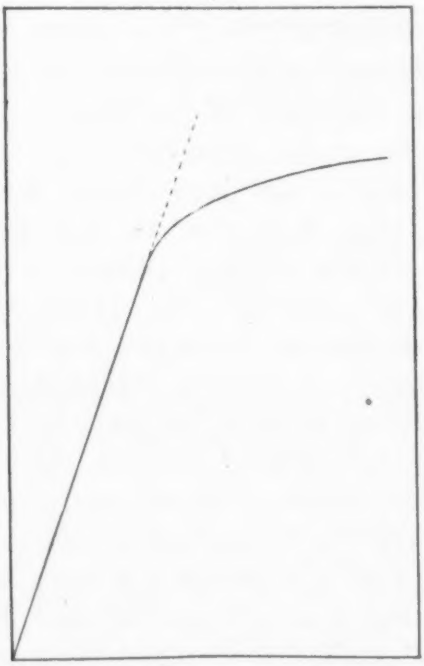


Fig. 3—Stress/Strain Curve after Reheating a Quenched Steel to the Optimum Temperature.

case-hardening steels may show the abnormality also in the core. There is a good deal, therefore, to be said for the practice of reheating case-hardened parts to a temperature of 150 to 200 degrees Cent. (300 to 390 degrees Fahr.) for a reasonable period, in order to induce in them the highest value of the limit of proportionality.

Instability of Volume

The second "defect" that is found in quenched steels, and particularly in those that when quenched acquire a high maximum stress, is instability of volume. This is a very large and complicated subject, because it is affected by so many factors. It is

proposed, therefore, to refer only to the fundamental aspect of the problem and not to those variable factors such as complexity of shape, of size, of quenching temperature and the like except insofar as they affect the main problem.

Instability of volume, and distortion, in quenched steel are connected definitely with the fact that the density of austenite is

Table IV

Changes in Maximum Stress and Limit of Proportionality Brought About by Reheating a Cold-Worked Steel to Various Temperatures

Reheating Temperature Degrees Centigrade	Limit of Proportionality tons/sq. inch	Maximum Stress tons/sq. inch
...	23.1	60.3
100	24.6	60.9
200	31.5	58.4
300	42.2	60.5
400	42.8	57.9
500	39.9	52.5
600	25.9	40.4

greater than that of its decomposition products. During heating, steel contracts as it goes through the Acl range—i. e. when the alpha iron changes to the gamma form. During normal cooling the reverse change occurs—i. e. the austenite in passing to martensite, to troostite, to sorbite, to pearlite, expands.

Now during quenching—which may or may not be "drastic," depending upon the nature of the steel under treatment, the breakdown of the ausenite is very incomplete, particularly insofar as the volume changes are concerned. For even though the steel departs markedly from the austenitic condition, it will not, at any rate in its greater bulk, pass beyond the martensitic state, otherwise it would not be hardened. Martensite appears definitely to be based upon alpha iron and, therefore, is less dense than austenite which is based upon gamma iron. The change from austenite to martensite during quenching is, however, bound to be only partial and rarely complete, and therefore the volume change of gamma to alpha iron is rarely complete.

Speed of Quenching

Another factor that influences the volume change is the speed of quenching. For with variation in this speed will come variations in the extent to which the austenite has decomposed. Very

slowly cooled austenite (except in those steels like 25 per cent nickel steels that have their critical cooling range at a temperature below atmospheric) becomes changed entirely to pearlite. Less slowly cooled austenite is converted to troostite, while martensite is the product of the austenite when cooled still less slowly. In most steels the cooling has to be very rapid if no degradation of the austenite is to occur. The degree to which the austenite has altered is reflected definitely in the changes of volume that take place during the cooling of the steel, as it may be stated with relative accuracy, that pearlite on the one hand (with or without ferrite) and austenite on the other hand, represent the extremes of volume of the constituents. Martensite has a volume in between the two, while that of troostite approximates to pearlite.

Now in any quenched article there is a difference in the rate of cooling between the exterior and the interior. (In air hardening, this variation is not very great though appreciable). It may be said generally in fact, that each layer at a different depth from the surface of the article cools at a different speed. This being so, it is evident that there is likely to be some difference in constitution in every layer of the part. There seems, in fact, to be little doubt that this extreme statement is theoretically true. The practical extent of the variation will depend upon several factors—particularly the composition of the steel and the dimensions of the part under treatment. In the majority of parts, there is, at any rate, a difference between the outside and the interior, and many quenched parts contain austenite and martensite in the exterior, then a layer of more or less pure martensite, succeeded sometimes by a core of troostite.

Granted that there may be austenite in the exterior of a part that has been quenched, and an absence of austenite in the interior, it is easy to see that the densities of the two parts will be notably different. Probably no part of the article is normal in value, but the greatest abnormality will be in the part containing austenite. Here, the density will be greater than is normal and consequently there will be a constant tendency to expand. For it must not be forgotten, that the presence of austenite denotes a very definitely unstable substance—produced by violent undercooling, and just as the seeding of an undercooled solution of photographer's hypo results in the crystallization of a great part of

the dissolved matter, so may the various things that happen to the steel result in the alteration of the austenite.

It is this instability of the austenite and the consequent liability for change of the volume of the whole article that is of importance. If the difference in density in the various portions of the article were fixed and permanent they would be unimportant. Unfortunately they are not so, and sometimes the change of volume which occurs after the part has been put into service is definitely detrimental. As austenite is the product of specific conditions that may be altered, notably by the conditions of subsequent service of the steel part, this constituent may readily change. Austenite is definitely preserved by pressure and in fact it seems very probable that it owes its continued existence in many quenched steels to the pressure exerted upon it by the martensite which surrounds it. If, therefore, this pressure is relieved during service, the austenite is likely to change—to martensite—and, therefore, to expand. Similarly the austenite is very ready to change to martensite (or to a further decomposition product) if heated, so that by this treatment, again there is produced a permanent expansion of the article. Thirdly, as the austenite and martensite press upon each other, the whole article is likely to be in a state of stress exerted between the contiguous elements. If the part is treated in such a way by the imposition of further stresses that these stresses are redistributed and altered or rearranged, the whole stress system is likely to be upset and the pressure on some of the austenite relieved. As a result, the austenite expands and the whole article changes density and shape. Naturally such treatment is received by many quenched parts in service, with the result that they definitely change their shapes.

In view of these probabilities it seems to be desirable that definite steps should be taken to bring the quenched steels into as stable a condition as possible with respect to their volume. What is said here applies only to parts that ordinarily are used in the hardened state, because those that are subsequently tempered at any high temperature, are automatically put into a stable condition of volume when they are converted into sorbite. The best way of treating the fully hardened parts is to submit them to a stabilizing heat treatment, which removes much of the unstable austenite.

It is found that reheating to quite low temperatures has a definite effect upon the volume of fully hardened steels. If heated to 100 degrees Cent. (212 degrees Fahr.) for a prolonged period, the steel definitely changes—there being first of all an expansion and then a contraction. After a long time the steel settles down to a constant volume. A similar result is attained by reheating to 200 degrees Cent. (390 degree Fahr.) but is brought about more rapidly. The net result of the operation is always a contraction and the higher the temperature the more rapidly is the contraction brought about. Eventually, however, the volume of the steel becomes steady and further reheatings to the same temperature, does not affect it.

In view of the need for retaining the hardness of a quenched part, it is not desirable to heat it up to any such temperature as very rapidly gives a stable volume. The tempering effect is much too powerful. It is necessary, therefore, to choose some treatment whereby the steel can be made to approximate to its most stable volume and at the same time be prevented from losing an undue proportion of its hardness. It is doubtful whether these two things can be achieved at one and the same time, for the perfectly stable volume means an absence of unstable constituents and this in turn means generally a reversion to a soft metal. Martensite is not a stable substance, but if it is destroyed the hardness of the steel part is destroyed with it. A compromise, therefore, seems to be essential and the best treatment appears to be that which will at any rate get rid of the austenite in the steel—thus removing the most unstable element in the material. This can be done by reheating to a temperature of approximately 200 degrees Cent. (390 degrees Fahr.). The more prolonged the treatment at this temperature—within reason and the bounds of commercial practicability—the better.

Spontaneous Fractures

The evil results of a failure to stabilize the volume of a steel is seen in the spontaneous fractures that frequently occur in parts that have been hardened and left in that state without any further treatment. Such diverse parts as taps, valve springs, and die-blocks are known to break explosively if allowed to stand in the fully quenched state. Usually it is stated that the fracture is due to the release of imprisoned stresses. This is quite true, but the rea-

son for the stresses is the very uneven volume of the steel in its different parts and the release of the stresses comes because the steel changes its volume. All these hardened parts contain a variety of constituents from austenite downwards. The austenite is notably unstable and is very ready to change by expansion into martensite. The fluctuation of temperature to which any part is normally susceptible is often sufficient to initiate this expansion. This necessarily brings about a change in volume within the part and therefore a change in the distribution of the stresses. It is easy to imagine how the operation may proceed to the point of producing very high stresses at some point—sufficient to cause rupture, and the subsequent action of the residual stresses is sufficient to cause an explosive disruption of the quenched article.

It can be seen, therefore, that the two most conspicuous inherent defects in fully quenched steels, can be remedied, or at least rendered harmless, by one and the same operation—namely a prolonged tempering at a temperature between 150 and 200 degrees Cent. (300 to 390 degrees Fahr.). By such a treatment the low limit of proportionality is raised very notably and at the same time the volume of the parts are rendered much more stable and less likely to change. Both these alterations are definitely beneficial to the finished article, and it is strongly suggested that such a treatment should be generally given to quenched steels. It may be objected that the basis for all these observations is the existence of austenite in the quenched steels and that austenite is but rarely found—being the product of very high quenching temperatures (such as are not used) applied to very high carbon steels (such as are rarely used). This objection would, however, be based on the assumption that austenite must be present in relatively large masses if it were to exercise its deleterious effects. This is not true at all. The austenite may be in very small units—tiny crystals mixed in with the martensite, and there is no doubt that in this form austenite is a very widely distributed constituent of quenched steels. The evidence for it is too bulky for a short paper, but is quite conclusive. Granted this fact then, the other points dealt with herein follow quite naturally, and steps should be taken to counteract their evil effects.

DISCUSSION FOLLOWING JEFFRIES AND ARCHER'S PAPER ENTITLED "THE HARDENING OF STEEL," PRESENTED AT THE FIFTH ANNUAL CONVENTION OF THE SOCIETY, PITTSBURGH

Paper Published in September, 1923 Transactions

CHAIRMAN H. M. BOYLSTON: I have been hoping that Dr. Sauveur would be here to discuss this capable paper, but I don't think he has arrived, and I think in fairness to him I should make one statement; sound one little note of warning here. Some quotations from Sauveur were included in the introduction to this paper. We should be very careful not to jump to the conclusion that because in the X-ray spectrometer and similar work we have a different method of testing, or different experimental method, that it is necessarily the one which is going to give us the answer. I think without attempting in any way to detract from the wonderful work of Jeffries, Archer, Bain, and others who have devoted a great deal of time to this, that we must take their statements with reservations until such time as other investigators have an opportunity to test the X-ray spectrometer and to give their interpretation of the data obtained. That is not intended as a criticism of the gentlemen named; it is simply a note of warning, not to swallow things whole too rapidly, for fear we may get metallographic indigestion. (Applause).

At least one other laboratory in this country, I believe, has now an X-ray spectrometer at its disposal, the Watertown arsenal at Watertown, Mass., and I was hoping that Dr. Langenberg would be here to tell of some of his results. I still hope that he will publish some of them.

I do not think that we have come to the time when we can discard the microscope for the study of these things, because refinements in microscopic methods, methods of preparation of specimens, etc., are already showing that we haven't reached the limit there, and I feel quite confident that in the near future we may have some results on the basis of microscope work which are going to show things that we have not understood thoroughly before.

I can't say much more than that, because the author hasn't presented his paper yet. I have seen some of his results, however, and am very much in hopes that he will consent to publish them later on.

The meeting is open for discussion. Unless there is a unanimous decision to close the discussion at this time, we will continue it but there are two more papers on the program, and I urge you to make your discussions snappy, but not to feel that you are being crowded out, because there is always the opportunity of writing a discussion, however brief it may be.

Are there any verbal discussions on this paper?

DR. S. L. HOYT: First of all I agree with what Professor

Boylston has said about the necessity for using caution in interpreting the results gained by the spectrometer, as wonderful an instrument or tool as that is in our hands today.

As to the paper proper, it is a long one and covers a big field, and as I read it over I had simply a flock of ideas come to me, so that any attempt to present them at this time I think would be futile. I think you would have a mean time listening to all that I might have to say if I were to attempt to discuss the paper as it really deserves to be discussed, so I shall confine myself to just one or two remarks.

First of all, as to the definition of hardness, as I understand the authors, they intend that to apply simply to their presentation, and do not wish to imply that it should be used universally as a definition of hardness. I think that question ought to be discussed this afternoon at the Symposium on Hardness, and I may have something to say further at that time.

Secondly, the evidence presented on the effect of size of grain on hardness is very interesting, and in many ways is quite conclusive, that is, that as the grain size decreases, the hardness increases. Of course that is a thing which is well known. I wish the authors, however, in some future paper would attempt to carry their idea a little further and to show by what mechanism the extreme resistance to deformation of martensite is secured.

In recent months I have been working on the deformation of single crystals, as well as poly-crystalline materials, and with the slip interference theory in mind, I soon saw it would be necessary to extend their reasoning somewhat to account for all that I was able to observe, and I might say in answer to Professor Ellis it seems logical to me that the introduction of a softer constituent of microscopic or submicroscopic size could easily lead to an increase in hardness. My reason for that is, briefly, that while the Alpha brass is commonly ductile and plastic, still when subjected to hydrostatic pressure it has practically the same resistance as a very much harder material. In other words, the plastic metals are very resistant to hydrostatic pressure, and without going into detail, I think I can see that plastic deformation in an aggregate of that kind implies hydrostatic pressure on the softer particles, therefore, that effect would lead to an increase in hardness.

Secondly, while the authors have considered a tremendous amount of evidence, it seems to me that in presenting it they have presented largely those portions which best substantiate their theory and possibly other evidence has been left out which might be more difficult to explain.

Take, for example, the relationship between hardness and specific volume. In 1920 there was some very careful work done on that relationship, and it was found that specific volume parallels hardness very

closely. I am referring now to hardness as measured by the Marten's sclerometer, and not to Brinell hardness.

You will recall in their paper the authors point out that steel attains its maximum value at about 0.6 per cent carbon. Now when the hardness is measured by the sclerometer, it attains its maximum value at the eutectoid point, which coincides perfectly with the measurements on specific volume; that is, they both attain their maximum values at the same carbon content. Therefore, I suggest that the authors may possibly have overlooked that bit of evidence and its bearing on their theory. The reason for the failure of the Brinell test to locate the true maximum in hardness I think is very simple to explain, because the Brinell test falls down over that range of hardness, and is incapable of giving accurate measurements of the hardness.

Mauer, the German investigator, has pointed out this relationship between specific volume and hardness and uses it as the basis of a theory to account for the hardness of steels, and while he did his work quite independently of myself, we both seem to have arrived at about the same conclusion, which is, that the hardness of martensite is due more largely to the effect of the carbon atoms in forced solution in the Alpha iron, rather than to the fineness of the grain.

In closing, I certainly do not want to neglect to congratulate the authors on presenting this interesting paper, and also to congratulate the society on having such a paper for its consideration.

CHAIRMAN H. M. BOYLSTON: I hope Dr. Hoyt will be able to assemble some of the evidence that he has, and present it later on in the form of a paper or written discussion.

DR. S. L. HOYT: I certainly shall do that if the occasion arises, and I anticipate it will.

R. S. ARCHER: We do not wish to give the impression that there should not be caution in accepting new theories or new evidence, but I would like to point out very decidedly that X-ray evidence is only a part of the large amount of evidence to which we referred. It is all very well to point out the need for caution, but I would like to ask these gentlemen, who have expressed that need, a few specific questions.

I have already referred to the fact that the British had not given Merica any too much credit for his work, but neglected to say that this X-ray evidence for which we are indebted has not only been obtained in this country, but also abroad, at the Swedish Metallographic institute by Dr. Westgren, and that those results are pretty widely accepted over there. Therefore, we are not presenting X-ray evidence which is the result of our own work, or of work which has been carried out to substantiate any preconceived theories we may have had. We are using and presenting evidence which has been developed independently; there has been more than one laboratory

doing this kind of work, perhaps only one in this country, but in the neighborhood of a dozen all over the world.

Then I would like to ask these gentlemen who doubt the evidence the following questions: First, do they question that Alpha iron has a body-centered cubic lattice?

Secondly, do they question that Gamma iron has a face-centered cubic lattice?

Third, that iron between 768 and 900 degrees Cent. has a body-centered cubic lattice?

Finally, do they question that martensite shows a body-centered cubic lattice?

I would like to know just what the need for caution concerns. So far as I can see, these facts are fairly simple, they are experimental evidence, not theories.

As to the evidence which Dr. Hoyt has referred to, that we have not included, we have made a fairly complete, and we believe conscientious endeavor to find all of the evidence bearing on the subject. Of course we have not completely accomplished this. There is evidence that no one ever finds; a lot of evidence in the German publications we have not been able to cover. We would be very glad to have any evidences bearing on the subject from anyone who is willing to give them. So far as we know, the conception as presented at this time is consistent with all known facts about steel, although, of course, it does not attempt to explain all of those facts. But if there are any facts with which it is not consistent, we would be very glad to know them.

CHAIRMAN H. M. BOYLSTON: I would like to say just here that we cannot intelligently question evidence until we have an opportunity to refute it or confirm it. That is exactly what I wish to point out. Until we can have further published evidences or confirmations or refutations of evidence obtained, we cannot really intelligently discuss it. That is the reason that I am asking for caution in accepting interpretations of evidence that may, however, be perfectly good.

E. C. BAIN: I want to speak about the chart that was shown at the last. It reminds me of those charts that Dr. Howe used to use for his students, and they are very fine. Although I am, perhaps the only one here who has spent any great time with the X-rays, I am very eagerly awaiting corroboration from others. Dr. Westgren, in Sweden, made X-ray studies almost simultaneously with me and his results are essentially in perfect accord with mine, but I am eagerly awaiting further reports to see that I have made no mistakes about the conception of the crystallographic changes of iron. I think we will have them reasonably soon, too.

About the chart, you will recall that the fine grained martensite was shown with its polyhedral grains at random within the original grains

of austenite. That may have been just a convenience for drawing it, but it doesn't strictly represent the facts. The preferred orientation of the new finely divided ferrite, (Alpha iron) that first grows in the original grains of austenite, depends very closely upon the orientation of the old austenite, and in at least one specimen I was able to show that ferrite of slight extent, at least in one thin plate, was formed. I infer, then, that the tiny polyhedral grains are only a tool of delineation and do not represent too closely the facts.

It is well known, how the straight lines of martensite are shown in the old austenite grains; I might say, how rectilineally they are marked, and so on. That is due to the fact that the new ferrite forms in the cleavages of austenite, and I have a theory which will come out later in papers, depicting the mechanism by which the body-centered iron forms out of the old face-centered iron and to some extent must depend on the orientation of the parent austenite. The drawing could easily be corrected to bring us up to date, showing the little grains of martensite bearing some geometrical relation to orientation of the parent grain.

DR. HOYT: I don't want to give out the impression that the evidence which has been drawn on the basis of X-ray diffraction patterns is weak. As a matter of fact, it is some of the best evidence which can be secured by physical means; and the answers to Mr. Archer's questions are very simple, namely, that Gamma iron is face-centered, Alpha and Beta iron are body-centered; martensite is body-centered, and martensite gives a pattern which is characteristic of extremely fine grained material, with approximately random orientation.

The word of caution which I threw out was as to how we were to interpret or utilize the information thus gained in explaining such things as hardness and hardening and plastic deformation. The mechanism of plastic deformation follows, somewhat indirectly from the X-ray evidence, rather than directly, and therefore the exact route by which you arrive at your final conclusion as to what is happening has to be guided by other considerations.

R. S. ARCHER: That is the thing I wanted to bring out by those questions. It seemed to me that such expressions of doubt might raise a question in many minds and might give the impression in many minds that this X-ray spectrometer is a new-fangled toy that we cannot trust much at present, whereas I think actually those who have studied it most feel it is quite reliable, and that the results obtained are quite reliable.

As far as the structure of Alpha iron is concerned, the body-centered cubic structure of Alpha iron, there has been very abundant confirmation of that, not only in this country, but in Europe.

DR. S. L. HOYT: The authors in the paper seem to feel that Grard is the only one who has noted the increase of hardness at low tem-

pering temperatures. I have recently run across two other investigators who have found the same thing, Mauer, for example. Mauer noted the thing first in 1908, I believe it was, and ascribed it to experimental error, but on subsequent work he repeatedly found the same thing. There does not seem to be any doubt that there can be, under certain circumstances, an increase of hardness on low tempering temperatures.

I would be interested to see an explanation from the authors as to why martensite sometimes increases in hardness while at other times it remains somewhat unaffected by tempering at 100 degrees Cent.

O. W. ELLIS: With regard to further evidence respecting the essential differences between the Alpha, the Beta, and the Gamma constituents, I have been working for some little while on the effect of the critical temperatures on the forgeability of steel. Unfortunately, I have not been able to obtain a sample of pure iron with which to work. I have been taking however, small samples of various steels and subjecting them to various drops under a drop hammer; I have found in the low carbon steels, about 0.10 per cent carbon, that there is practically a straight line relationship between the amount of deformation and the temperature of forging for all temperatures up to A_3, that beyond A_3 there is a straight line relationship existing over a fairly wide range of temperature also, but that at A_3 there is a marked change in the forgeability of the material.

Might I ask here whether any member could inform me where I could get a rod of relatively pure iron, electrolytic iron, or Armco iron, about half an inch in diameter, to do a little work on practically pure iron, because I would like to investigate the A_2 change in a purer iron than I have actually been using.

The point that I want to make here is this, that so far I have observed no change at A_2, while there is a definite sign of a change at A_3, not a large one, but a definite one.*

CHAIRMAN H. M. BOYLSTON: Do you know the sulphur content of the steels you are working with?

O. W. ELLIS: I am making analyses at the present time on the steels.

MAJOR A. E. BELLIS: Mr. Nead might help out on that.

O. W. ELLIS: I did try the American Rolling Mills Company, but they were unable to supply me with the rod. They could supply sheet, but not rod.

H. J. FRENCH: If the speaker will be satsified with electrolytic iron, remelted in a vacuum, and will see me in the exposition hall this afternoon, I am sure we can make some arrangement to supply him with the material he wants.

*A far more complete investigation of this low carbon steel has now been made, and the speaker as a result, desires to retract his statement respecting the A_2 change. A small but quite distinct change occurs at A_2, the steel becoming slightly harder.

O. W. ELLIS: Thank you very much.

CHAIRMAN H. M. BOYLSTON: I am reliably informed by the man who has done the experimental work, that he believes that he has an example of martensite which does not show completely, at least, the Alpha form of lattice-work under the X-ray tests. I am trying to obtain some definite evidence from him. Perhaps he is wrong, but if he has such information we, too, ought to have it. We are after the truth, and if this paper expresses the truth, I think we ought to strengthen it by further experimental work. The only warning that I wanted to sound is that before we draw final conclusions, we must have more confirmation of experimental evidence, and we must have the reactions of other minds in the form of interpretation.

I think we had better close the verbal discussion on that, at present.

WRITTEN DISCUSSION BY H. C. KNERR: As a member of the society and a student of physical metallurgy, I feel deeply indebted to Dr. Jeffries and Mr. Archer for preparing this paper and making it available to us in the TRANSACTIONS.

Whether the conclusions are accepted in full or not, there is no doubt that this and the associated papers by the same authors constitute a monument in metallurgical literature—a monument of progress, and a "tombstone" to a horde of confusing theories, conjectures and enigmas that have thrown mystery about the hardening of steel from ancient days right down to the present time.

Science has been defined as classified knowledge. In this sense, the present paper must rank high as a scientific achievement. The authors have not here announced any startling discovery or invention. They have patiently explored a tangled mass of existing evidence, picked the essentials, analyzed, verified and classified them, and with the keenest logic, given us a clear and reasonable statement—a statement that explains in a few pages, and in straightforward terms, what volumes have failed to clarify before.

It is such work that smooths the path of research, simplifies the problems of the engineer, and makes for great strides in the advancement of science.

Our society may justly be proud to have papers such as this is in its TRANSACTIONS, and men of such caliber on its roll.

NOTES FROM THE U. S. BUREAU OF STANDARDS*

High Temperature Tensile Tests of Steel

TESTS carried out during March at temperatures up to 1200 degrees Cent. on a commercial nickel-chromium-iron alloy show that the static proportional limit of this alloy in short time tests, inferior at temperatures below 450 degrees Cent., is above that temperature superior to that of any of the many steels which have been tested. The apparatus which is being designed for continuous loading at high temperatures is nearly ready for use and a report on "Available Data on the Properties of Irons and Steels at Various Temperatures," covering the literature on the subject and with an extensive bibliography has been prepared for the joint session of the A. S. T. M. and the A. S. M. E. to be held in Cleveland in May.

Relation of Quality of Steel to Its Carburizing Properties

This work is still far from complete but it has progressed to a stage where the results, which are partly corroborative of the previous work of Ehn and partly in apparent disagreement, are being summarized in a progress report for distribution to co-operating and interested parties as a basis for further discussion and to solicit suggestions which will be of use in deciding on further methods of attacking the problem.

Corrosion of Metals

The work which the Bureau is carrying on in co-operation with the A. S. T. M. on the corrosion of metals is beginning to yield some interesting data. There is, however, the difficulty of interpreting the information obtained correctly and until this can be done with greater certainty it is not wise to draw definite conclusions. One surprising feature of the work is that at least in the case of some alloys the alternative immersion test, in which the specimen is first suspended in air and then in the corrosive medium is not as severe as the simple immersion test. A great deal of work has been done in the comparison of methods of suspending the specimen in the corrosive medium and tentative conclusions have been drawn as to the most suitable method for specimens of several shapes. A paper describing the apparatus developed is being prepared for presentation at a forthcoming meeting of the A. S. T. M.

Phospor Bronze Bearing Metal

The Bureau of Standards, announces that standard sample, No. 63, phosphor bronze bearing metal, is now being issued with a provisional certificate.

*Information obtained from Technical News Bulletin No. 84. Published by the Department of Commerce, Bureau of Standards, Washington.

Purification of Hydrogen

It has been pointed out in previous numbers of the bulletin that in the liquification of hydrogen a very pure gas is necessary. The method employed by the Bureau of Standards for determining impurities present in what would ordinarily be considered extremely pure hydrogen is of interest. Oxygen is removed from the hydrogen by passing it through a platinum wire heater which causes a combination of oxygen and hydrogen to form water vapor. In order to determine the amount of oxygen which had passed this heater an analysis was carried out during March in the following way. Gas which had passed the heater was then allowed to flow through a condenser cooled with ice to remove most of the water, a tube cooled with liquid air to remove the remainder of the water, and a tube cooled with liquid hydrogen to freeze out nitrogen and any oxygen in the uncombined state. After this the hydrogen passed through a gas meter. Material frozen out by the liquid hydrogen was freed from hydrogen, vaporized and sent to the gas chemistry section of the Bureau for analysis. A preliminary analysis on 28 liters of hydrogen indicated 0.005 per cent of oxygen. A second more reliable analysis on 98 liters of hydrogen indicated 0.0008 per cent. This quantity is entirely negligible.

Camera for Photographing Specimens of Corroded Pipe

For some time the Bureau has been carrying on an investigation of the corrosion of pipe. It was important to secure photographs of the specimens and a camera has recently been designed for this purpose in the Bureau's photographic laboratory. To date, several pieces of corroded pipe have been photographed and very fine negatives obtained. These show the entire surface of the pipe in one continuous piece. It is expected that the camera will play an important part in the soil corrosion work now being carried on.

Refractories for Platinum Melting

Through a series of tests (briefly described in April TRANSACTIONS) in which various troubles were gradually eliminated, a crucible made of 85 per cent 140-mesh, electrically fused zirconia (which had been extracted with hydrochloric acid to remove surface iron) and 15 per cent alumina was found to be mechanically strong and to give excellent results in the melting of thermocouple platinum. A crucible made of 100 per cent zirconia, not acid washed, served as a container for platinum which proved to be only 9 to 15 microvolts positive to the same platinum melted in lime or thoria and should, therefore, serve for most commercial platinum. The platinum does not wet these crucibles so that the latter do not deteriorate rapidly and the button is readily cleaned.

NOTES FROM THE U. S. BUREAU OF MINES*

Synthetic Iron Studies

A CO-OPERATIVE agreement has been arranged between the British Columbia Bureau of Mines and the Department of the Interior whereby the Northwest experiment station of the United States Bureau of Mines at Seattle, Washington, will assist the first-named organization in establishing the best conditions for converting steel scrap, tin-plate scrap, and sponge iron concentrates into foundry iron and steel, through the medium of the electric furnace. The expense of this investigation will be borne by the British Columbia Bureau of Mines.

This work is a continuation of the laboratory work on synthetic iron previously done at Seattle by the Bureau of Mines. It is expected that the results will be applicable to the production of gray iron from sponge iron. The tests will include observations on the relation of charge to product, methods of controlling the composition of the product, power consumption, costs, etc. The furnace is of the Greene (Heroult type), three-phase, acid-lined, and of 3000-pound capacity.

Radium Research

Installation of essential equipment in the new radium research laboratory of the Department of the Interior, located at the Bureau of Mines offices in Washington, has been completed. Collections of radon can now be made at intervals of four to 10 days, according to the amount desired. The decomposition of ammonia by alpha radiation from radon will be the first experiment with radon. The radiation of a mixture of carbon nonoxide and hydrogen will be the subject of later experiments. Pure ammonia and pure carbon monoxide have been prepared and stored over mercury. The preparation of pure samples of gases will be continued, to include hydrogen, oxygen, carbon dioxide and electrolytic mixture of hydrogen and oxygen, these gases to be radiated with radon subsequently. This work is in immediate charge of Dr. D. C. Bardwell, assistant physical chemist, Bureau of Mines.

Temperatures in Blast Furnaces Using Charcoal

A study of temperatures in blast furnaces using charcoal as fuel has been completed by Department of Interior engineers at the Minneapolis experiment station of the Bureau of Mines. While nearly all the iron produced in this country is from blast furnaces using coke fuel, some furnaces are being operated on charcoal. The charcoal iron is usually manufactured for special uses, as in parts of automobiles. The tem-

*Information obtained from March and April, 1924, Press Memorandums of the Department of the Interior, Bureau of Mines, Washington.

perature data on smelting charcoal iron were needed chiefly for comparison in the general study of blast furnace problems. It was found that the temperatures under which charcoal furnaces are operated are lower than is permissible in coke practice. Furthermore, it was learned that the principal factor in causing this difference is the low sulphur content of the charcoal compared with the higher quantity of sulphur present in coke. In fact, the effect of sulphur in the blast-furnace charge is even more important than was hitherto believed.

Hot Metal Mines

In some of the mining fields of the West, the comfort and efficiency of the workers are greatly impaired by the high temperatures existing underground. Some mines cannot be worked because of inefficiency of miners due to high temperature, although they would be worked if this factor were corrected. The results of a study of effective temperatures for still air conditions and their application to mining, made by the Department of the Interior in co-operation with the American Society of Heating and Ventilating Engineers and the United States public health service, at the Pittsburgh experiment station of the Bureau of Mines, and in the field under actual working conditions, are given in Serial 2563, copies of which may be obtained from the Department of the Interior, Bureau of Mines, Washington, D. C.

Zirconium

Zirconium occurs mainly in two minerals, baddeleyite and zircon, according to Bulletin 212, recently issued by the Department of the Interior, through the Bureau of Mines. Most of the baddeleyite ore is found at Sao Paulo, Brazil. It is sold in this country in a natural mixture with zircon, under the trade name of zirkite, and contains about 75 per cent zirconium dioxide. Many placer deposits derived from the disintegration of granitic rocks carry zircon. In this country a deposit of zircon sand has been located at Pablo Beach, Fla., and as much as 3 per cent of some of the auriferous sands of Idaho and other states have been found to be zircon mixed with monazite.

Considerable attention has been directed toward zirconium in recent years on account of reports that this element gave unusual properties to ferroalloys. Nickel-zirconium alloy has been suggested for knife blades and cutting tools, inasmuch as it is said to be noncorrosive and nonstaining.

Zirconium oxide (zirconia) has been investigated as a refractory because the melting point of this compound is about as high as that of any other known oxide. Zirconium salts also have some importance; they have been used for weighing silk, as mordants in dyeing, and for many other purposes.

With these new investigations of zirconium and its increased commercial uses, there have also been attempts to improve the methods of determining this element, but at the present time there is much to be desired in the speed and accuracy of these methods.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION 124. *Why is nickel never used in tool steels? It is understood that nickel combines with ferrite to form a solid solution in steel and that solid solutions are harder than pure metals, hence it ought to make steel harder. Also nickel is said to lower the critical temperature, and if so should make steels easier to quench and harden and they would not require as high a temperature for heating. Why is it that an element which apparently is so valuable is not used more as an alloying element in tool steels?*

QUESTION NO. 125. *What is a suitable test to apply to a carburizing box before installing it in service?*

QUESTION NO. 126. *How should steel castings be specified and purchased?*

QUESTION NO. 127. *How should tool steel be specified and purchased?*

QUESTION NO. 128. *What heat treatment, if any, could be given to the steel of the following composition which would produce the physical properties as given below?*

	Per Cent
Carbon	0.65
Manganese	1.37
Silicon	0.37
Phosphorus	0.024
Sulphur	0.033
Tensile Strength	70,000 to 85,000 lbs. per sq. in.
Yield Point	32,000 to 40,000 lbs. per sq. in.
Elongation in 2 in.	12 to 18 per cent
Reduction of area	18 to 25 per cent

ANSWERS TO OLD QUESTIONS

QUESTION NO. 93. *What are the more common methods of quenching ordinary taps? Are they quenched all over and the shanks drawn, or are they quenched only on the threaded portions; or are both the threaded portions and the tangs quenched, leaving the center portion of the shanks soft?*

QUESTION NO. 96. *Can the structure of a piece of steel be determined by the microscope applied to the fracture of a cross section, without polishing and etching the fracture, say of a stamping die 6 x 2 x 3½ inches, that has been hardened and broken in half, that is, are the different structural phenomena known as austenite, martensite, sorbite, ferrite, etc., so determinable?*

ANSWER. By W. M. Mitchell, E. I. du Pont de Nemours and Company, Wilmington, Del.

In general, no. The surface of a fracture is so irregular that satisfactory focussing is impossible with powers high enough to resolve pearlite or martensite, etc. It might be possible to recognize certain appearances in fractures, under the microscope, when it was known that martensite, pearlite, etc., was present, which when seen again could be identified as caused by such constituents, but this is doubtful. If it were possible to do this, the laborious process of grinding and polishing that is everywhere indulged in would long ago have been done away with.

QUESTION NO. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel 6 x 2 x 3½ inches?*

QUESTION NO. 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc?*

QUESTION NO. 110. *Do notched bar impact specimens give more uniformly constant results than an un-notched bar?*

QUESTION NO. 114. *Is it possible to obtain an accurate conversion table for obtaining Brinell hardness number from the Rockwell or scleroscope values?*

ANSWER. By D. L. Colwell, metallurgist, Stewart Manufacturing Corp., Chicago.

It is not possible to obtain an accurate conversion table for obtaining Brinell hardness number from the Rockwell or scleroscope values. Scleroscope readings are greatly influenced by the condition of the surface of the sample, the mass of the sample, and local or surface hardness. Brinell readings are only partially affected by surface hardness, and are independent of the mass of the sample but are influenced to a certain extent by the plasticity of the metal. Rockwell readings are still more independent of surface hardness, but are greatly influenced by core or internal hardness and, only partially influenced by plasticity. A conversion table, therefore, would only be accurate for one particular sample, where all of these properties are fixed. Each machine has its own sphere of usefulness where it is more satisfactory than the others, but any one of them cannot do the work of all three.

QUESTION NO. 116. *Can a zinc bath be used as a heating medium in substitution for a lead bath? If not, what are the objections to its use?*

ANSWER. By D. L. Colwell, metallurgist, Stewart Mfg. Corp., Chicago.

A zinc bath cannot be used as a substitute for a lead bath as a heating medium, due to several reasons. First, zinc attacks and pits the steel. The amount of this attack increases with temperature, time of contact and amount of impurities in the zinc. Second, the zinc adheres to the work much more than lead. Third, zinc oxidizes more readily and at higher temperatures fuming and metal loss would be excessive. Fourth, the higher oxidation at higher temperatures would cause a scum on the surface of the bath, which would interfere with its proper functioning.

ANSWER. By Dr. W. M. Mitchell, E. I. du Pont de Nemours and Company, Wilmington, Del.

The chief objection to molten zinc as a heating medium in

place of the lead bath is that zinc volatilizes much more readily than lead and at a lower temperature. The melting point for zinc is just under 800 degrees Fahr., and at that temperature it is decidedly volatile. At the quenching temperature of steel copious fumes of zinc oxide would be evolved which could probably not be controlled with charcoal, so that considerable loss of zinc would result, to say nothing of whitening up the whole works with zinc oxide. Another factor of considerable importance is that zinc and iron are soluble in the solid state, so that iron or steel when immersed in the molten metal will become impregnated on the surface with a layer of zinc. While this would have the advantage of rust proofing the articles, their hardness and strength would be impaired, such, for instance, as the cutting edge on a tool.

QUESTION NO. 117. *Does cooling molten metal rapidly eliminate segregation?*

ANSWER. By Dr. W. M. Mitchell, E. I. du Pont de Nemours and Company, Wilmington, Del.

Yes, the more rapid the cooling the less the tendency to segregation. When solidifying rapidly, the metal remains more nearly in the condition in which it was cast; that is, there is less opportunity for low melting point compounds or impurities to be forced, by solidification of the exterior layers, to the still hotter interior of the ingot or casting.

QUESTION NO. 118. *Is a small percentage of chromium desirous in carbon tool steel? What is its advantage or disadvantage?*

ANSWER. By Dr. W. M. Mitchell, E. I. du Pont de Nemours and Company, Wilmington, Del.

A small percentage of chromium would not be objectionable in a tool steel, provided its presence was known so that heat treatment could be modified accordingly. The effect of chromium is to retard the transformations which take place during heat treatment, so that longer soaking and higher temperature are necessary as compared with carbon steel. Chromium also lowers the eutectoid

ratio, and hence a steel with a small content of chromium would be equivalent to slightly higher carbon in a given steel. Chromium will produce a finer grained and harder steel without increase in brittleness, and should be considered as desirable rather than undesirable. Its disadvantages are: more care required in heat treatment, and, if carbons are being judged by the fracture test, this will be misleading unless the effect of chromium in causing finer grain structure is recognized.

QUESTION NO. 119. *What is the advantage of sulphuric acid as a quenching medium?*

QUESTION NO. 120. *How does the carbon content affect the secondary hardness of high speed steels?*

QUESTION NO. 121. *What are thumb-nail cracks?*

ANSWER. From a paper by F. S. Nicholds published in a recent issue of *Brown Bailey's Journal,* Sheffield, England.

Those who have had experience of or taken any interest in tool-making have at some time or another seen the half-moon or thumb-nail cracks which appear most frequently in chisels, hatchets, plane irons, and other kinds of thin or wedge-shaped tools.

It has been known for many years that the characteristic thumb-nail crack could arise from two different causes:—

1. From the use of brittle types of steel, as for example, those containing free cementite; and
2. From cold forging operations.

As is well known, all carbon tool steels in the soft condition containing carbon in amounts appreciably less than 0.9 per cent are composed of ferrite crystals (free iron) which are very soft, and pearlite crystals which are composed of alternating plates of iron carbide and pure iron. As the carbon increases, the pearlite areas increase and the steel becomes harder, until at 0.9 per cent

the whole of the iron is monopolized to form pearlite. If further carbon to amounts appreciably above one per cent, is added, a part of the carbon will exist as free carbide, cementite, and when occurring as envelopes around the crystalline grains of pearlite makes the steel very brittle. The fine envelopes of hard and brittle material (cementite) offer little resistance to cracking. Also the difference in co-efficient of expansion of cementite and the material in which it is embedded favors the origin as well as the extension of a crack. To avoid thumb-nail cracks from this cause, it is therefore desirable to avoid the use of steel containing free cementite, especially if in the subsequent rolling or forging operation any appreciable degree of cold working is likely to be done.

Thumb-nail cracks can, as previously stated, be produced by cold forging, whether the steel contains free cementite or not. In forging tools the smith who likes to turn out a smart-looking job will use the flattener down to, or beyond, the temperature at which a red color is visible in the material. By forging the tool in this manner he assumes that he has refined its structure and also toughened or made it more springy, but he is generally ignorant of the fact that in many respects he is damaging the steel rather than improving it. In material of the same kind, the fineness of the granular structure does increase as the temperature at which the material has been finally forged or rolled gets lower. This is an improvement down to a certain point, *i.e.*, if it is not carried below a visible red heat. Below a dull redness (say 1150 degrees Fahr.) all carbon tool steels are brittle and sensitive to shock, and any mechanical operation such as hammering, swaging or flattening has a great tendency to start cracks, which may be so small to begin with that they cannot be distinguished by the naked eye or even through a hand lens. These small cracks or checks open out during the subsequent quenching operation in hardening and then can easily be seen. This brittleness at temperatures below dull redness which occurs in most kinds of steels, as well as tool steel, is known technically as blue brittleness because it is supposed (erroneously) to occur in the neighborhood of the temperature at which the blue tempering color is formed.

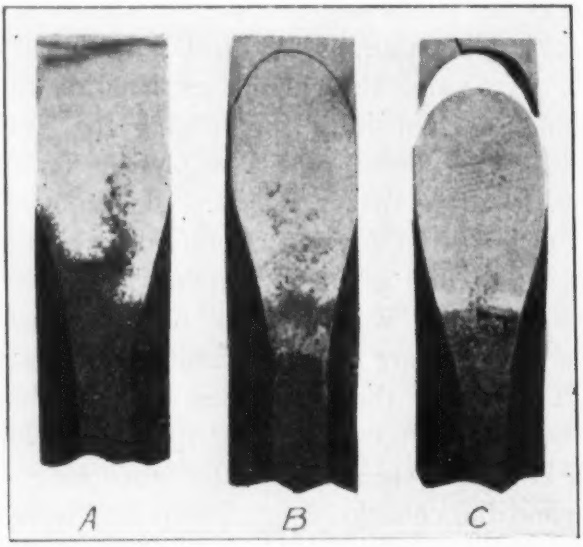
It is supposed, however, that thumb-nail cracks become visible on hardening (omitting those due to free cementite) only when an appreciable amount of cold forging work has been done on the

tools; and cannot be produced in hardening if the forging work is completed at, or above, a red heat. This statement appears in the literature of the subject and seems to have been accepted as satisfactory. When thumb-nail cracks have arisen in hardened tools made apparently from suitable steel, the cause has been ascribed entirely to "cold work" during forging operations. No attempt appears to have been made to determine whether thumb-nail cracks could originate entirely in the hardening operation.

Some time ago the writer had to deal with an epidemic of thumb-nail cracks in pneumatic chipping chisels. The tool steel was of the usual kind, containing 0.80 to 0.90 per cent carbon, with low manganese. Accepting the current explanation the writer was disposed to blame the tool-smith for forging the chisels too cold. In order to give ocular proof of his negligence on this point the smith was asked to forge twelve chisels. Six from an initial temperature which enabled the forging operation to be complete without any cold working, and a similar number heated so that an appreciable amount of cold working was necessary to finish them off. The forged chisels were closely examined for cracks, but none were found. The smith then hardened and tempered them in the usual way by heating up to about 2 inches beyond the cutting edge to correct hardening heat and water quenching, up to about half-an-inch beyond the cutting edge. The points were then rubbed bright with a piece of sandstone, and the heat remaining in the back part of the chisel was allowed to spread until on the brightened point a purple color was produced. The hardened and tempered chisels were then cooled off and examined for thumb-nail cracks. Five out of the six cold worked ones and also (to the writer's surprise) four of the other six had a thumb-nail crack on the point; the crack in each case having its convex side toward the cutting edge of the chisel. The accompanying photograph shows (a) hardened chisel perfectly sound, (b) hardened chisel with a thumb-nail crack near the cutting edge and (c) hardened chisel with point broken off through a thumb-nail crack. The cracked points were easily broken off by knocking them on the anvil face. The depth of the semicircular crack could be easily distinguished on the subsequent fracture as part of its surface was tinted by the purple color during the tempering operation. These cracks are generally distinguishable from those due to free cementite. The

latter are scalloped and irregular along their length, because they follow the free cementite outlines; the former have a clean sweep along a smooth curvature.

The results of this experiment showed that an apology was due to the tool-smith and to every member of his craft for undeserved blame, and, that thumb-nail cracks can appear in the hardening operation even when the forging of the tools is finished at or above a red heat.



Having arrived at this conclusion it was obviously desirable to find an explanation for cracks which occur without regard to cold forging temperatures or the fact that the steel contains free cementite. We already know that thumb-nail cracks can be produced in steels containing free cementite and also in lower-carbon steel tools by heavy forging through the blue brittle stage and in both cases are entirely due to brittleness. It is therefore reasonable to ask whether the water-hardening operation itself may not produce in many steels that degree of brittleness from which thumb-nail cracks may arise.

When a piece of tool steel is quenched from above its hardening temperature, parts of it are in a permanently expanded condition. The steel is very highly stressed and may be regarded as in the act of being pulled apart. It may resist the tendency to

break very easily or otherwise. Also the steel, after hardening, is in its most fragile condition. If the hardening stresses are greater than the steel can withstand, cracking or breaking is inevitable. This is the condition of tools which break during the quenching operation or shortly afterward.

The tendency of hardened steel to break should not be measured by its hardness. Pieces of air-hardening steel, for example, after water hardening, oil hardening and air hardening may be equally hard, but they are not equally brittle, nor are they each stressed to the same extent. The chances are the water-hardened specimen would fracture before it is cold, the oil-hardened specimen would be apt to develop cracks from what appear to be insignificant surface defects, whereas the air-hardened specimen, while being equally as hard as the others would be sound and such surface defects as it may have had in the unhardened condition will not increase to a visible extent.

It seems reasonable, therefore, to suppose that the tendency of steel to form and develop hardening cracks depends on the

1. Intensity of hardening stresses,
2. Balance of hardening stresses,
3. Resistance of the steel to stress effects.

The intensity of the stresses developed in hardening steel is not measurable, or rather, we know of no means whereby they may be determined quantitatively. We may form estimates of a qualitative kind, based on experience with different quenching media and the manner in which a particular object and a particular quenching medium are brought into contact with each other. And, similarly as to the balancing of hardening stresses, this depends also on the quenching process and the shape of the article quenched. A sphere, for example, which is made from sound steel and hardened throughout, will stand an almost unlimited amount of mishandling without cracking in the hardening process, whereas a cylinder must be handled carefully. Makers of ball and roller bearings are emphatic on this point.

The resistance of material, qua material, to the stresses set up on hardening is approximately constant and might conceivably be measured by known methods used for the mechanical testing of steels in general. Means of reducing the resistance

are known, as, for example, when a steel is quenched from temperatures high enough to coarsen its crystalline structure, its tendency to crack is known to be greater. This may be partly due at least to the weakened resistance of the material, though due to some extent, no doubt, also to the increased stresses developed by greater variations in the rate at which different parts of the steel objects are cooled. We are, unfortunately, not able to evaluate these tendencies separately, and cannot therefore measure the intensity of the one in terms of the other. Nor may we regard the results of controlled variations in hardening temperatures as a satisfactory comparative measure of the tendency of a steel, otherwise sound, to crack in hardening or to splinter in service.

Some means of reducing the resistance of material to a uniform degree, or to a measured extent, would be valuable as far as it enabled one to observe the effects of variations from a standard hardening process, or so far as it enabled one to observe the tendency of one steel over another to become dangerously stressed on hardening. Such means may ultimately be found in modifications of the ordinary pickling process.

Brittleness may be developed in unhardened steel by pickling in a bath of hot dilute sulphuric acid. This fact was first observed by Hughes in 1880. He found that during this operation the steel absorbed some of the liberated hydrogen and remained brittle until the hydrogen had dissipated by allowing the steel to lie a long time in the air, or by heating it for a shorter time. Hughes' observations have been repeatedly confirmed, and the precautions he devised to get rid of pickling brittleness have become part of industrial practice. The fact may be conclusively illustrated by taking a piece of high carbon steel wire tough enough to bend on itself without fracturing. After pickling similar pieces, any one of them tested immediately after removing from the dilute acid bath will break short on bending. Other pieces left in the air will gradually evolve the absorbed hydrogen, and bend through a greater angle before breaking the longer they are left before testing. But any piece reheated for a short time to 250 to 300 degrees Cent. immediately after pickling, loses its absorbed hydrogen at once, and will bend double as easily as the unpickled wire.

Material in the unhardened or in the hardened and fully-tempered condition is not appreciably stressed, and may also be very tough. The embrittling effects of pickling will not, therefore, be likely to crack them. On the other hand, objects in the hardened condition are highly stressed, and it is only a question as to how near they are to breaking and to what extent the resistance of the material is decreased by pickling, which determines whether they crack or not. As the embrittling effects of pickling may be varied and to some extent controlled, this method may obviously be useful in studying the influence exerted by different ways of quenching on the intensity of hardening stresses and their location.

Coming back to thumb-nail cracks it may be shown that when no cracking occurs in thin steel which can be made equally hard by water-quenching and oil-quenching, the tendency to form cracks, by actually forming them in the pickling bath, is greater in the water-hardened steel. This might be expected. But, on the other hand, the tool maker has a choice in the kind of steel he will use for a particular purpose. With due regard to mass effects he may choose to make chisels, hatchets, cane knives, cleavers, and many other kinds of edged tools from steels higher in carbon and lower in manganese content which must be water-quenched to produce the desired degree of hardness. Or he may choose to make them from steels lower in carbon and higher in manganese which harden of course in water, but which become equally hard when quenched in oil. The pickling test carried out on tools made in each of these ways indicates that the tendency to crack on corners and cutting edges is greatest in the water-hardened specimens. This conclusion, however much it may surprise the maker of high priced crucible tool steels, which are usually low in manganese, is confirmed by manufacturers of the kind of tool referred to in regard to those tools operating under searching conditions of use.

Some tests were made on two classes of steel. One contained carbon 0.73 per cent and manganese 0.36 per cent, with the usual precautionary limits of surphur and phosphorus. The other contained carbon 0.53 per cent and manganese 0.72 per cent and higher amounts of sulphur and phosphorus. Strips of each were rolled four inches wide by 3/16 inch thick, care being taken to finish the rolling between 1380 and 1470 degrees Fahr. The material

was pickled after rolling to make certain that no cracks existed in the experimental materials.

Pieces of the higher carbon material were hardened in water from 1470, 1560 and 1650 degrees Fahr. Those pieces hardened from 1560 and 1650 degrees Fahr. were very apt to crack on Brinelling, and showed evidence of thumb-nail cracks, but all the pieces showed thumb-nail cracks after pickling. The lower carbon steel, after hardening in water, was equally hard, but less brittle. It did not crack on Brinelling to anything like the same extent, and no trace of thumb-nail cracks was found, except in the pieces hardened from 1650 degrees Fahr. On pickling, the pieces oil-hardened from 1650 degrees Fahr., thumb-nail cracks were formed, but to a much less extent than in the higher carbon steel.

The point in favor of the lower carbon and higher manganese steel is that in thin sections it can be made as hard by oil-quenching as by water-quenching. Comparative pieces in the oil-quenched condition did not crack on Brinelling, showed no evidence of thumb-nail cracks after hardening, and could not be made to crack by pickling, unless they were badly overheated before quenching.

It may be concluded that thumb-nail cracks arise from stresses due sometimes to cold working through the brittle range. More frequently, however, they arise from hardening stresses, and occur about corners and edges. As a piece of plane glass when heated and water-quenched, sheds its corners, so the hardened sheet steel tends to crack arc-wise. The tendency of steels of different composition to act in this way is emphasized by pickling. The safest and most economical remedy is to substitute oil-hardening for water-hardening. It follows that to meet extreme demands, the danger of cracking could be further minimized, so far at least as hardening is concerned, by air-hardening instead of oil-hardening. Steel of the right kind must of course be chosen to suit the selected hardening process.

QUESTION NO. 122. *What are the mechanical properties of stainless steel and stainless iron?*

QUESTION NO. 123. *What are the advantages of using a hot soapy-water quenching medium?*

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

INTERPRETATION OF COKE SURFACES AND STRUCTURES. By A. Thau, superintendent, Deuben Coke Plant, Halle, Germany, in *Chemical and Metallurgical Engineering,* Vol. 30, No. 8, page 306, 1924.

The author interprets the meaning of variations in coke appearance as affecting coke utility and gives a number of typical examples of vitreous carbon deposits on beehive and by-product coke.

CASTING METALS. By W. J. Reardon, Foundry editor, in *Metal Industry,* March, 1924, page 103.

The author discusses a variety of melting and molding troubles and their solutions.

ELECTRIC REDUCTION FURNACE IRON. By R. C. Gosrow, consulting electrochemist, Chicago, in *Iron Trade Review,* April 10, 1924, page 982.

This article states that pig iron made in the electric reduction furnace is of high quality and is adapted to foundry and steelmaking use, and further states that economic conditions and inexperience of operators have retarded industry.

HEAT TREATING LOW-CARBON BARS FOR RIVETS. By C. B. Langstroth, consulting engineer, Milwaukee, in *Iron Age,* March 20, 1924, page 849.

In this article the practical application of the advantage derived from heat treating low-carbon steel is very clearly shown by the author's experience with rivets.

ETCHING. By Charles H. Proctor, plating-chemical editor, in *Metal Industry,* March, 1924, page 112.

This article gives accepted and reliable methods of etching for different purposes.

SHOWS KINKS IN BRASS CASTING. By E. G. Jarvis, general manager, Niagara Falls Smelting and Refining Co., Niagara Falls, N. Y., in *Foundry,* Feb. 15, 1924, page 134.

This is an abstract of a paper presented at a meeting of the Indiana State Foundrymen's association, Lafayette, Jan., 1924, and states that an important asset in successful operation is the knowledge of how to buy metal.

DISCUSS STEEL FOUNDRY WORK. By F. A. Melmoth, engineer for Braintree Castings Co., a subsidiary of Lake and Elliot, Ltd., Braintree, Eng., in *Foundry,* Feb. 15, 1924, page 143.

This article is an abstract of a paper presented at the annual meeting of the Institution of British Foundrymen, held recently in Manchester, Eng. It describes British practice and the common problems are stated. Annealing of all castings which must stand shock is urged.

CAST-IRON RETORTS FOR LOW-TEMPERATURE CARBONIZATION. By C. H. S. Tupholme, London, Eng., in *Chemical and Metallurgical Engineering*, March 24, 1924, page 471.

This article gives a description of a system designed to permit carbonization at moderate temperature and in a short time.

SOME FOUNDRY PROBLEMS. By A. H. Mundey, London Manager, Fry's Metal Foundry, London, England, in *Metal Industry*, March, 1924, page 104.

This is an abstract of a paper delivered at the joint meeting of the London section of the Institute of Metals and the Institution of Marine Engineers, London, Dec. 13, 1923, and discusses the general difficulties in casting metals and alloys as met in British practice.

THE STORY OF FERROCHROMIUM. By Frederick M. Becket, metallurgist, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y., in *Chemical and Metallurgical Engineering*, Vol. 30, No. 8, page 316, 1924.

This article, which is the second of three excerpts from the author's discourse, gives the industrial developments and utility of the material that made possible stainless steel and rustless iron.

THE TARNISHING AND DETARNISHING OF SILVER. By G. W. Vinal and G. N. Schramm, in *Metal Industry*, March, 1924, page 110.

The authors discuss the causes of tarnishing and compare the methods of removal. The properties of moss silver are also given.

MOLYBDENUM IN CAST STEEL AND IRON ROLLS. By W. N. Bratton, in *Iron Age*, No. 112, page 1509, 1923.

This paper states that molybdenum is now used in four classes of rolls, low-carbon steel, high-carbon steel, sand-cast rolls and chill-cast rolls. It has a direct effect upon the ferrite as a toughening agent and upon the carbides as a strengthening and wear-resisting agent, and decreases fire-cracking of the surface. Molybdenum steels can easily be manufactured, heat treated and fabricated.

CORROSION OF ELECTROLYTIC IRON. By W. E. Hughes in *Chemical and Metallurgical Engineering*, No. 29, page 536, 1923.

In studying the corrosion of electrolytic iron, the author states that the history and in particular, the composition of the bath from which the iron was plated, should be known. Samples of electrolytic iron plated from a bath containing iron chloride and calcium chloride rusted, after having lain a few weeks, whereas samples plated from a bath containing iron sulphate and magnesium sulphate showed no rust after having lain for years.

Reviews of Recent Patents

By
NELSON LITTELL, Patent Attorney
110 E. 42nd St., New York City
Member of A. S. S. T.

1,479,507. Furnace Charging. Robert B. Kernohan and Mordan W. Hall of Pittsburgh.

This invention relates to a "Dolomite Gun" adapted to replenish the supply of lining material along the margin of the bath in an open-hearth furnace during the operation of the furnace by shooting the material across the furnace to the proper place along the back wall thereof. In the use of prior apparatus of this kind a large portion of the finely divided lining material is lost by being carried away by the furnace gases and may be carried beyond the furnace chamber and deposited in the checker work. The present invention overcomes this loss by forming the charge for the gun in a paper bag which is strong enough to be shot across the furnace by compressed air from the gun and which will be burst by the impact to deposit the lining material at the desired point, on the back wall of the furnace.

1,480,230. Process of Carburizing Steel and Iron. Toyokichiro Tashiro of Tokyo, Japan.

This patent states that a deep penetration of the carbon into the metal can be effected in a comparatively short time by causing carbon monoxide to form in the carburizing chambers and making it act in its nascent state and under superatmospheric pressure on the metal to be carburized. To carry out the process, the metal is packed with carbon power, iron oxide and manganese peroxide in an air tight retort and heated to 800 or 950 degrees Cent. to form carbon monoxide and increase the pressure within the retort, the freshly formed carbon monoxide under pressure quickly carburizes the metal. In one example given by the inventor after two and one-half hours heating on pieces 1.2 inches thick the pieces were carburized to a depth of one-half inch.

1,481,338. Annealing Furnace. Chauncey C. Baldwin of Perth Amboy, N. J. Assignor to Standard Underground Cable Co. of Perth Amboy, N. J.

This patent is for an improvement in annealing furnaces of the type in which the retort is supported over a quenching tank, the water of which seals the open bottom of the retort and in which the charge when annealed is lowered directly downward into the water in the tank. The improvement consists in supporting the retort on

a cantilever seat at one end of the tank so that the platform with the charge thereon may be raised and lowered for insertion into and removal from the retort and moved from below the retort to the loading platform at the other end of the tank by means of a traveling overhead crane without obstruction to its movement from the retort or its support. No part of the crane or sling is below the water level in the tank.

1,472,738, Aluminum-base Alloy and Method of Treating It. Robert **S. Archer and Zay Jefferies of Cleveland, O. Assignors to** Aluminum **Company of America of Pittsburgh, Pa.**

This invention provides an aluminum-base alloy which after having been worked and quenched is relatively soft and workable and which will retain these properties for an indefinite period when maintained at room temperatures.

The inventors have discovered that certain aluminum-base alloys when free from added magnesium and containing not less than 3.5 per cent copper will age very little after having been worked and quenched from a temperature above 500 degrees Cent. (932 degrees Fahr.) if maintained at normal or room temperature. Consequently their discovery provides an aluminum base alloy which when worked and quenched may be reworked by cold forging, rolling or the like at any time thereafter, providing the temperature in the meantime is kept at an average or normal temperature. A further advantage of the alloy is that it may be artificially aged at temperatures between 100 and 175 degrees Cent. (212 to 347 degrees Fahr.) to increase the tensile strength and improve other physical processes in a manner similar to the natural aging of aluminum-base alloys heretofore used.

The essential constitution of the alloy is that it shall contain no appreciable magnesium and not less than 3.5 per cent copper. In addition to copper it may contain other elements such as manganese, chromium, silicon and zinc. The particular composition capable of giving the best physical properties is copper 4.5 per cent, manganese 0.75 per cent and silicon 0.75 per cent, which has been worked and quenched from a temperature of about 500 to 540 degrees Cent. (932 to 1004 degrees Fahr.), and may be artificially aged from about 100 to 175 degrees Cent. (212 to 347 degrees Fahr.) Iron in appreciable amounts decreases the maximum strength obtainable but its effect may be largely counteracted by the use of silicon which should be added in sufficient amounts to equal or exceed the iron content.

The claims are drawn to cover a worked aluminum-base alloy free from magnesium and containing not less than 3.5 per cent copper with or without various amounts of manganese and silicon and capable of having its physical properties improved by aging above 100 degrees Cent. and also the method of treating the worked alloy which comprises quenching it from above 500 degrees Cent. so as to make the

alloy immune from natural aging but capable of being artificially aged at temperatures above 100 degrees Cent.

1,482,563, Superhardened Steel and Process of Producing the Same. Axel Gustaf Emanuel Hultgren, of Gottenborg, Sweden.

This invention proposes to superharden metals which have been hardened by ordinary heat treatment by subjecting them to cold working in a manner to cause permanent deformation and make the surface still harder than that done by the heat treatment. The inventor claims to have discovered that after the ordinary heating and tempering, the metal may be further hardened or superhardened by cold working to the extent of causing a permanent deformation. In a specific example of the application of the proposed process a hardened ball bearing is rotated for a short time while loaded to about 10 times it rated capacity, which exerts a pressure upon the surfaces being treated beyond their elastic limit and effects the working of the surface which gives permanent deformation and hardening of the metal adjacent the surface. In the manufacture of the superhardened articles it has been found desirable by the inventor to subject the worked article to low tempering heat to relieve the stress of working.

1,482,585, Method of Decarbonizing Ferro Alloys. Hugh C. Sicard of Niagara Falls, New York, Assignor to United States Ferro Alloys Corporation of New York, N. Y., a corporation of New York.

This patent relates to a method of decarbonizing ferroalloys in bessemer converters whereby the loss of the alloying ingredients through oxidation is prevented. The metal in the alloy is protected from oxidation in the bessemerizing process by the presence of titanium, preferable as a titaniferous ore such as rutile. The charge is melted in an electric furnace and sufficient carbon is added to bring the carbon content to 6 to 10 per cent, sufficient silicon to make the silicon content of from 1 to 6 per cent, and a sufficient quantity of titaniferous ore to give a titanium content of from 1 to 10 per cent. After being melted in the electric furnace the mass is charged into the bessemer convertor and blown. The silicon is first oxidized, then titanium, then the carbon, and when the carbon content has been reduced to the desired amount, the air blast is stopped. By this means a low-carbon ferroalloy may be produced without oxidation or serious loss of the chromium or other alloying ingredient.

1,483,298, Alloy Comprising Iron, Nickel, Chromium, Molybdenum. Pierre Girin, of Paris, France. Assignor to Societe Anonyme De Commentry Fourchambault and Decazeville of Paris, France.

The object of this invention is to produce an alloy having a high mechanical resistance at high temperatures and capable of preserving its properties after a prolonged exposure to high temperatures. The

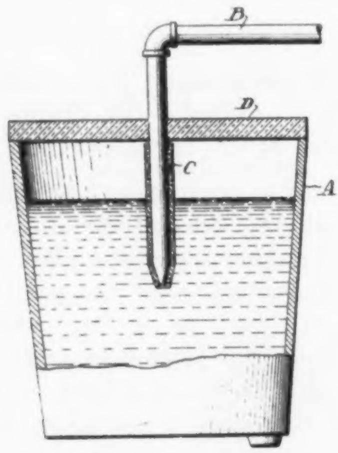
inventor proposes to produce an alloy capable of being molded, forged, rolled or drawn without difficulty, and possessing at the temperature of 800 degrees Cent, (1472 degrees Fahr.) a resistance almost equivalent to that of cold iron, one which is non-fragile and practically inoxidizable at a high temperature, and whose properties are strictly reversible. The alloy is composed of:

> Nickel, 60 to 70 per cent, chromium 10 to 15 per cent, molybdenum 1 to 3 per cent, manganese 1 to 2 per cent, carbon 0.3 to 0.6 per cent, iron forming the remainder.

The alloy thus obtained forms a solid homogeneous solution and is not affected by subsequent treatment.

1,484,465, James R. Billings, of Chicago, Ill., Assignor to J. R. Billings Iron and Steel Company, of Chicago, Ill., a corporation of South Dakota.

This invention relates to an improvement in making iron and steel castings whereby castings or ingots, substantially sound and free from blow holes or the like may be produced. In the operation of the

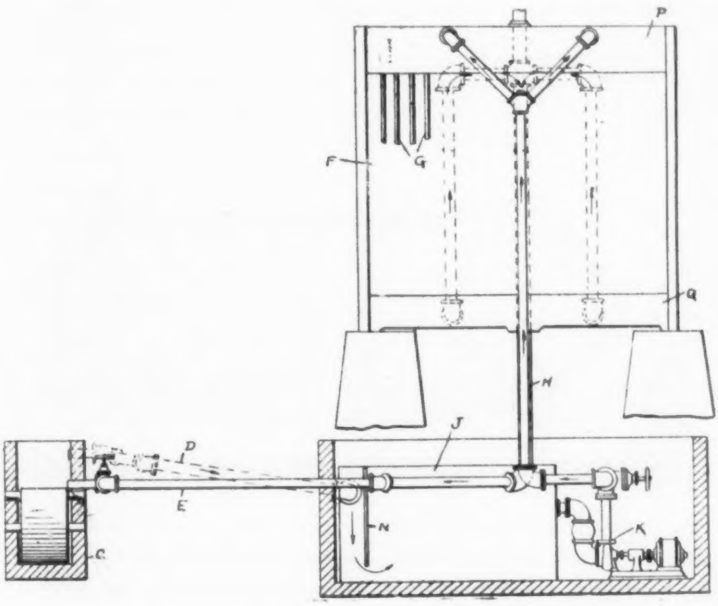


invention the molten metal, whether from the cupola, bessemer converter or open-hearth furnace is charged into the ladle *A* provided with a cover *D* and the air is blown in through the pipe *B* provided with a refractory coating *C*. The air which is introduced oxidizes a portion of the carbon monoxide, hydrogen or hydrocarbons present in the molten metal and this generates sufficient heat to increase the temperature of the metal and its fluidity, without oxidation of the iron or substantial reduction of the total carbon content. After this treatment the iron is cast into ingots or other desired shapes.

1,485,134, Herbert A. Wright, of Detroit, Michigan. Process and Apparatus for Reducing the Temperature of Cooling Oil.

This patent describes a method and apparatus for reduc-

ing the temperature of oil in an oil tempering bath. In the drawing *C* is a tank or vat containing the oil through which the articles being treated are moved by means of an endless belt conveyor. The heated oil is passed through the pipe *D* into the settling tank *J* under the baffle *N*, permitting solid matter to settle out, and is then forced by the pump *K*



through the pipe *H* and tubes *G* of the radiator *F* where it is cooled and flows back into the tank *C* through the return pipe *E*. With the exception of the settling tank, the patent describes substantially the ordinary water cooling system applied to an oil bath.

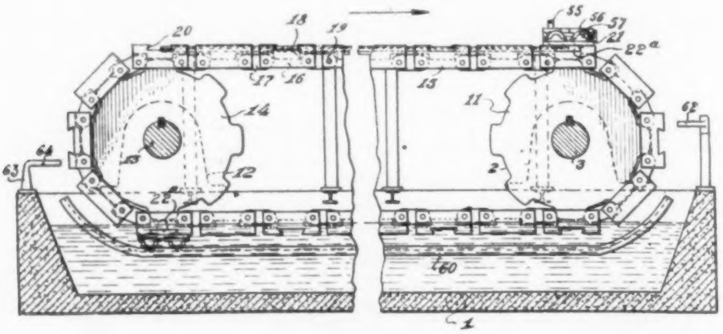
1,485,635, Manufacture of Ferrous Alloys and of Weatherproof Articles Therefrom. John Murdock Skelley, of London, Eng., Assignor to the Continuous Reaction Company, Ltd., of London, Eng.

This invention relates to an improvement in the so-called stainless steel manufactured from alloys of iron and chromium and the production of an alloy which, when exposed in a clean but unpolished condition (after drilling or machining) to the action of rain and sunshine will not become rusted in the course of a few days. It is different from the ordinary stainless steel in that this steel is weather resistant or stainless without being heat treated or polished. The preferred composition of the alloy is 12 to 24 per cent chromium, 0.4 to 3 per cent molybdenum, 0.95 to 0.85 per cent carbon, from 0.1 to 1.3 per cent silicon and the remainder of iron. The usual minor constitu-

ents of commercial steels have little or no prejudicial effect upon the weatherproof properties of articles made from this alloy.

1,487,530, Spring Forming and Tempering Machine. Jesse Allen Bowers of Wilkes-Barre, Pennsylvania, and Edward John Baumgarten of Canton, O.

This patent describes an apparatus for forming and tempering springs, consisting of a pair of endless chains, 15 passing over sprocket wheels 11 and 14, and in the lower course of the chains through the tempering bath in the receptacle. The alternate links of the chain, such as links 18 and 20, are adapted to carry the spring forming heads



21 and as these spring-forming heads near the right end of the apparatus the heated steel blank for forming the spring is inserted therein and as the chain passes over the sprocket 11 the forming heads are clamped together by means of the trip arms 62 contacting the cam closing means for the forming heads, which puts the steel blank into the desired form. With the spring blank retained in bent position the forming heads are passed through the tempering bath in the container 1 and then as the chains pass over the sprocket 14 the trip arms 64 release the cam clamps for the forming heads and the forming heads move apart so that the formed spring leaf can be removed. By thus holding the blank in the desired position in the forming head, during the tempering operation, the danger of warping and deformation of the spring leaves is greatly avoided.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Boston—Third Thursday.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

Chicago—Second Thursday.

Hartford—Tuesday nearest 10th of month.

Indianapolis—Second Monday.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth building.

Philadelphia—Last Friday, Engineers' club.

Tri City—Third Thursday.

BOSTON CHAPTER

THE Boston chapter of the American Society for Steel Treating held a meeting on April 18 at the General Electric Co., River Works, West Lynn, Mass. Plant visitation began at 2:00 p. m. and the foundries, press department, forging and welding shops of the plant were inspected. Following this the members and guests gathered in the dining room of the main office building for an excellent dinner, part of the expense of which was borne by the General Electric company. After a short business meeting, at which time reports were given by L. E. Zurbach, chairman of the local exhibits committee for the 1924 convention, on the progress being made with the sale of space, and by G. C. Davis, secretary of the chapter on membership. W. G. Mitchell, assistant manager of the General Electric company, extended a word of welcome and gave information as to the size of the plant, and their method of handling products manufactured.

Dr. H. P. Hollnagel delivered the main address of the evening which was entitled, "The Physical Aspects of Hardness Testing." This paper was very well received and created a most active discussion. Major Bellis, visiting from the New Haven chapter of the society, lead the discussion giving a few remarks about the necessity for careful thought and work on this subject and told of some of the work accomplished by the hardness testing committee of the National Research council of which he is chairman. Dr. W. S. Dawson of the General Electric company then gave an illustrated lecture, showing pictures of Mt. Ktaadin, one of the most beautiful mountains in New

England. Although Dr. Dawson's talk did not concern steel treating and came at the end of a rather long day, it was exceptionally well received and appreciated by everyone.

This meeting was without question the best attended and most interesting meeting ever held by the chapter, there being 160 in attendance.

Plans were arranged for the chapter's meeting on May 16 when it will join with the Worcester chapter in a combined meeting. There will probably be plant visitation at Worcester followed by a banquet. The speaker will be Dr. Ancel St. John. This will no doubt be a very interesting meeting and the Boston chapter invites all of the New England chapters to attend.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held their regular April meeting on the tenth of the month at the Ohio Mechanics institute, Canal and Walnut streets. "Giving Tool Steels a Chance" was the title of a very interesting paper given by F. R. Palmer, assistant metallurgist, Carpenter Steel Co., Reading, Pa. The Cincinnati section of the American Society of Mechanical Engineers was invited to attend this meeting which resulted in a large attendance.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held a meeting on Friday, April 25, at 8 p. m. in the Cleveland Engineering society rooms, Hotel Winton. Edwin T. Jackman of the Firth-Sterling Steel Co., Chicago, presented a very interesting paper entitled "Stainless Steel." Mr. Jackman has made a special study of this subject and his connection with one of the largest manufacturers of stainless steel has afforded him ample opportunity to become acquainted with all of its different phases. His paper was very capably presented and considerable interesting and instructive discussion was brought forth. Dinner was served at 6:45 p. m., preceding the meeting.

DETROIT CHAPTER

On Monday, April 21 at 8 p. m., the Detroit chapter of the American Society for Steel Treating held a meeting on the fifteenth floor of the General Motors building. W. S. Bidle, first vice president of the society, gave a very interesting paper entitled, "Heat Treating." W. H. Eisenman, national secretary, also attended this meeting, and spoke to the attendance on the affairs of the society. Dinner was served at 6:30 p. m. in the club rooms on the fourteenth floor of the same building.

HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held a meeting on Tuesday, April 8, at 7:45 p. m. in the Hartford Engineers club rooms, 12 Haynes street, Hartford, at which time S. M. Havens, general manager of the Ingalls-Shepard division of the Wyman Gordon Co., Harvey, Ill., addressed the members, choosing for his subject, "The American Society for Steel Treating and the Executive." Mr. Havens is one of the national directors of the society and his presentation was very capably given. A lively discussion on several questions that had been offered by members of the chapter, was held following Mr. Havens' address. Dinner was served at the University club at 6:30 p. m.

LEHIGH VALLEY CHAPTER

On Friday, April 25, the Lehigh Valley chapter of the society held a meeting in the Easton Public Library building. P. F. McKinney, metallurgist, U. S. navy yard, Washington, the speaker of the evening, gave a very interesting paper entitled "Problems of the Steel Treater as Influenced by Pre-Natal History of the Material." Much valuable discussion followed this presentation.

MILWAUKEE CHAPTER

The Milwaukee chapter of the American Society for Steel Treating held a meeting on Thursday, April 24 at the Hotel Blatz, at which time Elmer Smith, Smith Inventions Co., Minneapolis, spoke to the members and guests choosing for his subject, "Oxyacetylene Welding and Uses of Liquid Oxygen." A very interesting discussion followed this presentation which was very capably given.

NEW YORK CHAPTER

An unusual treat was in store for those members of the New York chapter of the American Society for Steel Treating who attended the monthly meeting of the chapter in the rooms of the Merchants' association, Woolworth building, Wednesday evening, April 16. K. Honda, Japan's leading metallurgist, and one of the outstanding authorities in that field in the world, delivered a brief address on "Transformation." It was delivered in English but was somewhat difficult to follow. He dealt with the controversy as to the relations of alpha, beta, gamma and delta iron and propounded, by means of charts drawn on a blackboard, some of his own views on the subject. Edgar C. Bain, Dr.

Ansel St. John, Dr. Paul D. Mercia and Dr. John A. Mathews all briefly discussed Professor Honda's address and bore testimony to his standing among metallurgists of the world. The meeting was preceded by an informal dinner at which Professor Honda was a guest.

Another address presented the same evening was delivered by Arthur W. F. Green, metallurgist John Illingsworth Steel Co., Philadelphia, who, in an entertaining manner, recounted many of his experiences in coming in contact with some unique and anything but scientific methods of heat treating steel in his efforts to prove to the user that the product of the steelmaker is "always right."

NORTH WEST CHAPTER

On April 2 at 8 p. m., the North West chapter of the American Society for Steel Treating was given the opportunity of inspecting the plant of the Auto Engine Works, through the courtesy of Messrs. Mooney and Sweet, members of the chapter. The company had several aeroplane motors under repair, the parts of which had to be subjected to heat treating operations, and this was accomplished for the benefit of the visitors.

The chapter held their regular monthly meeting on April 21 at 8 p. m. at the Manufacturers' club. Elmer H. Smith, president of Smith's Inventions, Inc., spoke on the subject of "Oxyacetylene Welding and the Uses of Liquid Oxygen." Inasmuch as Mr. Smith is an authority on this subject, he gave a very capable presentation and made some practical demonstrations of various types of welding. This meeting was well attended.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a special meeting on Wednesday evening, April 9, at 8 p. m., at the Engineers' club in honor of Dr. Kotaro Honda, professor of metallurgy, Tohoku Imperial university, Sendai, Japan, who is visiting the United States at this time. Professor Honda addressed the chapter on "Some Important Problems in Metallurgy." He received a hearty welcome by those in attendance. The members of the Philadelphia section of the American Institute of Mining and Metallurgical Engineers were invited to attend this meeting. The meeting was preceded by an informal dinner in the club dining room at 6:45 p. m.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held a special meeting on April 4 at 8 p. m. in the auditorium of the Bureau of Mines at which time Dr. Kotaro Honda, bessemer medalist of 1921 and head of the department of metallurgy of the Institute

for Iron, Steel and other Metals, Imperial university, Sendai, Japan, spoke on "The Theory and Practice of Quenching Steel." Messrs Matsushita and Takagi, two of Dr. Honda's associates, were also present. Dinner was served at the University club at 6:30 p. m.

The chapter held their regular meeting on Tuesday, April 8, at 8:15 p. m. in room 209 of the Science building, Carnegie School of Technology, Schenley park. Prof. Harry S. Hower spoke on the subject of "Pyrometers." Professor Hower gave some practical demonstrations of the pyrometer and his presentation was very interesting.

On April 15 the associated engineering societies of Pittsburgh in co-operation with the War Department held a special meeting in the ball room of the William Penn hotel. Honorable Dwight F. Davis, assistant secretary of war, spoke to the societies on "Industrial Mobilization." Moving pictures were also shown. The participating organizations, Pittsburgh sections, were the American Society of Mechanical Engineers, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Chemical society, American Society for Steel Treating, American Electro Chemical society and Illuminating Engineering society.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a meeting on Friday, April 25, which began with plant visitation of the Brown Instrument Co. at 2:15 p. m. The members and guests then proceeded to the plant of the Leeds & Northrup Co. An informal dinner was served at 6:30 p. m. in the Leeds & Northrup Co.'s auditorium, the attending members being the guests of the company. The meeting was held at 8 p. m. in the same room, at which time A. H. d'Arcambal, metallurgist, Pratt & Whitney Co., Hartford, Conn., gave an illustrated paper entitled, "Carbon and High Speed Steels Used in the Manufacture of Small Tools." A general discussion of tool treating problems followed Mr. d'Arcambal's presentation. The meeting was very well attended and an enjoyable day and evening spent by all.

ROCKFORD CHAPTER

The Rockford chapter of the American Society for Steel Treating held its regular meeting on Friday evening, April 25, at the Nelson hotel at 8 p. m. V. A. Hain, George J. Hagan Co., Pittsburgh, gave a very interesting address on "Electric Heat Treating and Similar Furnaces." This paper was very capably presented and brought forth much discussion. Dinner was served at 7 p. m., preceding the meeting.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held a meeting on Tuesday evening, April 22, at 8 p. m., in the

Chamber of Commerce rooms, at which time Prof. V. O. Homerberg, Massachusetts Institute of Technology, Cambridge, gave a very interesting paper entitled, "The Detection of Defects in Steel Without the Use of a Microscope." An interesting and instructive discussion followed this presentation which was very capably given. A get-together dinner was served at 6:30 p. m. at the Highland hotel.

ST. LOUIS CHAPTER

The St. Louis chapter of the American Society for Steel Treating held their regular monthly meeting on March 31 at the American Hotel Annex. M. W. Atwood, sales manager for the Laclede Christy Fire-Clay Products Co., St. Louis, Mo., gave an address on "Mining of Clays for Clay Products," which was illustrated with four reels of motion pictures which his company made up in conjunction with the Bureau of Mines and which provided a very educative feature to all interested in steel treating. Following Mr. Atwood's presentation, Francis D. White, chairman of the chapter, gave a brief talk on "Steel Stamping" exhibiting samples of pressed steel parts as made by the National Enameling and Stamping Co., Granite City, Ill., with which Mr. White is connected. Dinner was served at 7 p. m. preceding the meeting which was very well attended.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held a meeting on April 11 at 8 p. m., at which time E. C. Smith, metallurgical engineer for the Central Steel Co., Massillon, O., gave a general talk on the subject of steel. Considerable discussion followed Mr. Smith's presentation.

TORONTO CHAPTER

The Toronto chapter of the American Society for Steel Treating held a meeting on Friday, March 28, at 8:15 p. m. in room 32, Mining building, University of Toronto. O. W. Ellis, professor of metallurgy, University of Toronto, gave a very interesting paper entitled, "Recent Views on the Structure of Metals and Their Application to the Hardening of Steel." Professor Ellis gave a very capable presentation and considerable valuable discussion followed. Dinner was served at the Whitborne Inn previous to the meeting.

TRI CITY CHAPTER

The chapter held a meeting on Wednesday, April 23, at the Davenport chamber of commerce. Elmer H. Smith, president Smith's Inventions, Inc., gave a very interesting paper entitled, "Oxyacetylene Welding and the Uses of Liquid Oxygen." Mr. Smith is an authority on this subject and his presentation brought forth much valuable discussion. Dinner was served at 7 p. m.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held a meeting on Thursday, April 24, at the Morgan Construction Co. R. F. Harrington, Hunt-Spiller Co., Boston, presented a paper, choosing for his subject, "The Foundry Metallurgical Department," which treated of the functions and possibilities of a foundry metallurgical department, the control of raw material, the control of the operation of molding sand and the heat treatment of cast iron castings.

Dinner was served at 6:45 p. m. in the restaurant of the Morgan Construction Co.

Plans have been completed for the organization of the Tri-City Technical council, which is an association of the technical societies in the Tri-Cities, the following organizations being represented in the council: American Chemical society, Illinois-Iowa section; American Society of Mechanical Engineers, Tri-Cities section, American Society for Steel Treating, Tri-City chapter; Davenport Engineers club and the Quad-City Foundrymen's association.

The following temporary officers have been selected: Chairman, H. Bornstein, Deere & Co., Moline, Ill.; vice chairman, Howard Rogers, Williams-White Co., Moline, Ill.; and secretary-treasurer, Harvey Soverhill, Davenport Locomotive Works, Davenport, Iowa.

One of the principal purposes of the organization of the council is to increase the civic activities of the technical men and organizations of the Tri-Cities. A brief outline of the plans of the Tri-City Technical council is as follows: The council will act as a clearing house for the various technical societies in the Tri-Cities and surrounding territory. It will act as a means of co-operation between the technical societies now in existence. A monthly bulletin will be issued, listing the meetings of the various societies. The council will act as an agency to prevent conflict of dates of meetings. At various times during the year, men of national reputation will be secured and meetings of general interest to all technical men will be held. The council will act as sponsor for educational courses to be given along technical lines. A technical library will eventually be established. The supply of technical books in circulation in the municipal libraries in the Tri-Cities is very limited, consequently a library committee of the council will be formed to recommend the purchase of certain technical works to the municipal libraries. A secretary will be employed to take care of the secretarial work of the council and also of the local technical societies. It is hoped that in time a permanent meeting place will be established. The plans for organization were submitted to each of the local societies and have been approved. Provision has also been made for the individual membership of the council. The council will be governed by a board of directors, selected from the affiliated organizations and from the individual membership.

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

ACHORN, L. A., (A-4), salesman, Arion Steel Co.; *mail* 239 Franklin street, Boston.

ALLISON, J. H., (A-3), vice president, E. J. Deckman Co., Pittsburgh.

ARION, H. F., (A-4), president, Arion Steel Co.; *mail* 239 Franklin street, Boston.

BAHMER, S. P., (Jr-4), student in metallurgical engineering, Ohio State university; *mail* 176 Fifteenth avenue, Columbus, O.

BAXTER, H. A., (S-4), Tacony Steel Co., Philadelphia.

BERCHTOLD, E. W., (A-2), sales engineer, Boston Consolidated Gas Co., Boston; *mail*, 266 Columbian street, Columbus, O.

BISHOP, E. R., (M-4), superintendent of forge department, Globe Malleable Iron and Steel Co., Syracuse, N. Y.

BITZER, E., (M-5), open-hearth clerk, Columbia Steel Corp., Pittsburgh, Cal.

BLACK, E. C., (M-4), elevator department, Baker Iron Works, Los Angeles, Cal.

BLOOM, J. R., (Jr-4), librarian, Sigma Rho Fraternity, School of Mines; *mail*, 412 Walnut street, S. E., Minneapolis, Minn.

BOVARD, M. W., (M-4), superintendent of inspection, Crucible Steel Company of America, Pittsburgh.

BURR, W. J., (M-3), Willys-Overland Co.; *mail*, 1025 Grand avenue, Toledo, O.

BYERS, W. B., (M-12), salesman, American Metallurgical Corp.; *mail* 80 Boylston street, Boston.

CLAMER, G. H., (S-4), Ajax Electrothermic Corp., Trenton, N. J.

CLYNE, C. T., (M-11), 422 St. James Place, Chicago.

COLE, F. H., (M-4), metallurgist, Walworth Manufacturing Co., South Boston.

DIEHL, K., (M-3), steel inspection department, Bourne-Fuller Co.; *mail* 1319 West 112th street, Cleveland.

EGBERT, R. J., (M-4), steel open-hearth department, Bethlehem Steel Co.; *mail* 405 West Broad street, Bethlehem, Pa.

ELY, C. C., (S-2), treasurer, Trimont Manufacturing Co., Boston.

ESQUILANT, H. E., (M-3), heat treater, Lark-Parkes, Ltd., Sydney, Australia; *mail*, 15 Ocean street, Woollahra, Sydney, New South Wales, Australia.

ETTINGER, M., (Jr-4), 1416 Pingree street, Detroit.

FRASER, H. J., (M-3), research assistant, International Nickel Co., Huntington, W. Va.

FREDERICK, W. H., (M-4), foreman, tool department, Brown Instrument

Co., Philadelphia; *mail* 132 East Wellens avenue, Olney, Philadelphia.

FRONICK, G. A., (M-3), welder, Budd Wheel Co.; *mail* 2745 North Croskey street, Philadelphia.

FUCHS, R. W., (A-5), sales engineer, Blaw Knox Co.; *mail* Box 915, Pittsburgh.

FURNESS, R. S., (M-4), metallurgist, A. C. Cars, Ltd.; *mail* Weston Park, Thames Ditton, Surrey, England.

GOLDA J. D., (M-3), chief metallurgist, Weirton Steel Co., Weirton, W. Va.; *mail* Bachelor's Club, 421 Washington street, Steubenville, O.

HAMILTON, F., (M-4), chemist, Witherow Steel Co., Pittsburgh; *mail* 1420 Fourth avenue, Coraopolis, Pa.

HARTEL BROTHERS AND COMPANY, (S-4), 307 Atlantic avenue, Boston.

HAUSER, S. L., (Jr-4), student, Lehigh university; *mail* 437 West Third street, Bethlehem, Pa.

HIGGINS, J. F., (A-4), salesman, Firth-Sterling Steel Co., Boston; *mail* 222 Broadway, Arlington, Mass.

HOLLAND, U .C. ,(M-4), lecturer, University of Toronto, Toronto, Ont., Canada.

HOOVER, G. C., (M-4), U. S. navy yard, Washington, D. C.

HOTTINGER, A. J., (Jr-4), student, Lehigh university, Bethlehem, Pa.; *mail* Kenvil, N. J.

JOHNSON, W. P., (M-4), tool room, Lucey Manufacturing Co.; *mail* 1529 Annan Way, Los Angeles, Cal.

JONES, J. E., (M-5), toolmaker, Columbia Steel Corp., Pittsburgh, Calif.

JOSEPHSON, H. G., (M-4), president, Eastern Tool & Stamping Co., East Saugus, Mass.

KREBS, F. W., (A-4), district agent, United Alloy Steel Co., 402 Keith bldg., Syracuse, N. Y.

LECLAIRE, H. J., (M-4), steel treater, American Laundry Machine Co., Rochester, N. Y.

LEWIS, H. S., (M-1), assistant general manager, Parish Manufacturing Co., Reading, Pa.

LINDQUIST, W., (M-6), 1414 Sixth avenue, S. E., Minneapolis, Minn.

LOOS, C. E., (M-4), mechanical engineering department, American Bridge Co.; *mail* 1121 Maplewood avenue, Ambridge, Pa.

LUCKINS, W. J., (M-4), foreman, Brown Instrument Co.; *mail* 2729 South Darien street, Philadelphia.

MAHONEY, G. A., (S-5), treasurer, Houghton & Richards, Inc.; *mail* 145 Oliver street, Boston.

MARSHALL, J., (S-4), Edward G. Budd Manufacturing Co., Philadelphia.

MAXWELL, E. J., (M-4), improvement production work, Walworth Manufacturing Co.; *mail* 125 McKinley avenue, Kewanee, Ill.

McCORKLE, I. B., (M-4), metallurgist, National Tube Co., Ellwood City, Pa.

McCUSTER, W. J., (M-4), heat treating department, Budd Wheel Co.; *mail* 3918 North Percy street, Philadelphia.

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